NASA Technical Memorandum

NASA TM - 100324

ANALYSIS OF CONTAMINATION DATA RECORDED BY THE IECM CAMERA/PHOTOMETER

By K. Stuart Clifton and Carl M. Benson

Space Science Laboratory
Science and Engineering Directorate

March 1988

National Aeronautics and
Space Administration
George C. Marshall Space Flight Center

MSFC - Form 3190 (Rev. May 1983)

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. NASA TM-100324	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Analysis of Contamination Data Recorded by the IECM Camera/Photometer		5. REPORT DATE March 1988
		6. PERFORMING ORGANIZATION CODE ES63
7. AUTHOR(S) K. Stuart Clifton and Carl M. Benson		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D.C. 20546		13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by Space Science Laboratory, Science and Engineering Directorate.

16. ABSTRACT

The Camera/Photometer was one of ten instruments comprising the Induced Environment Contamination Monitor (IECM) developed to monitor the contamination about the space shuttle Orbiter during early shuttle missions. This experiment consisted of two motion picture cameras, integrating photometers, and associated electronics enclosed in pressurized canisters and separated by 40 cm in order to make stereoscopic observation of particulates. The objectives of the experiment were to record the occurrence of particulates and to determine their velocities, sizes, and origins, as well as to measure the background brightness due to unresolved particles. Particle tracks were detected on over 1,800 data frames recorded during continuous operations throughout STS-2, -3, -4, and -9. This report discusses the analysis techniques employed in reducing the subsequent results, with an emphasis placed on particle size and velocity data. It also describes the operation of the overall experiment and some of the results obtained.

17. KEY WORDS Shuttle Contamination, Optical Instruments, Space Observations, Particulates	18. DISTRIBUTION STATEMENT Unclassified --- Unlimited

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	58	NTIS

MSFC - Form 3292 (May 1969)

For sale by National Technical Information Service, Springfield, Virginia 22151

TABLE OF CONTENTS

PRECEDING PAGE BLANK NOT FILMED

LIST OF ILLUSTRATIONS

PRECEDING PAGE BLANK NOT FILMED

TECHNICAL MEMORANDUM

ANALYSIS OF CONTAMINATION DATA RECORDED BY THE IECM CANERA/PHOTOMETER

I. INTRODUCTION

With the advent of the Space Transportation System (STS), new opportunities have been presented for astronomical and other optical observations in space. However, concern has long been expressed about the effects of spacecraft-generated contamination on the resulting data [1]. This contamination in the form of particles and molecules originates from the outgassing of materials and surfaces, cabin leaks, fuel droplets, dust and dirt, paint flakes, and ice crystals. In order to insure that the quality of optical observations was not significantly impaired due to such Orbiter-produced contamination, a Contamination Requirements Definition Group (CRDG) was established, representative of NASA, the Department of Defense, and the European Space Agency (ESA). The purpose of this group was to collect, analyze, and define payload contamination requirements as input to the design and operation of the STS. As a result, a number of criteria were developed as guidelines for the limitation of Shuttle-produced contaminants [2]. Subsequently, an instrument package, the Induced Environment Contamination Monitor (IECM), was developed to monitor in real-time the Shuttle environment on early STS missions in order to ascertain if these guidelines were in fact fulfilled [3].

The IECM, consisting of ten instruments, was designed to monitor different aspects of Orbiter-induced contamination including gaseous emissions, molecular depositions, and particles, as well as the resulting effects on optical surfaces. The instruments comprising this self-contained unit included a Dew Point Hygrometer, Humidity Monitor, Cascade Impactor, Optical Effects Module, Passive Sample Array, Temperature-Controlled and Cryogenic Quartz Crystal Microbalances, Air Sampler, Mass Spectrometer, and Camera/Photometer. Descriptions of each of these instruments, their operations, and results may be found elsewhere [4-9].

The Camera/Photometer was designed to monitor the particulate environment and background brightness due to unresolved particulates around the space shuttle during orbital operations. Such contamination poses potential degradation to observations by reducing the overall signal-to-noise ratio and introducing spurious signals into the data. Even moderate generation rates of particles could seriously impair the usefulness of space-borne infrared instruments which can detect very small particles at large distances. The ability of the Camera/Photometer to make optical measurements of the occurrence of particulate contamination including sizes, velocities, and potential sources, as well as of the integrated background brightness due to unresolved particles, made its inclusion in the IECM highly desirable.

II. INSTRUMENT

The Camera/Photometer instrumentation consisted of two 16-mm photographic cameras, attached photometers, and associated circuitry [10]. Both a schematic and a photograph of the instrument are shown in Figures 1 and 2, respectively. The cameras were each enclosed in pressurized canisters and separated by 40 cm to allow the stereoscopic determination of particle distances. Each canister contained a standard atmospheric mixture of gases pressurized to 10^5 N m^{-2}. A relative humidity of 20% was introduced to minimize film damage at higher temperatures and other problems such as static markings, sticking, and reticulation.

Observations by each of the cameras was conducted through a quartz window at the top of the canister. A baffle system placed on top of the canister minimized the amount of stray light impinging on the window and raising the background light level. The baffle was designed to reject scattered light to levels below 10^{-14} $B_\odot$ (where $B_\odot$ is the mean solar brightness equal to 1.98 x 10^5 stilb) for solid angles greater than 60^o from the solar axis. The dimensions of the baffle, however, were necessarily constrained by the overall size of the IECM unit, and light reflected from surfaces was in fact an occasional problem.

Once power was applied to the system, the two cameras operated continuously throughout the mission with the instruments electronically slaved together for synchronous operation. Each camera had a nominal film capacity of 4000 frames which was sufficient for approximately a 7-day mission. The cameras were equipped with 18 mm f/0.9 lenses each affording a nominal 20^o half-angle field of view. In actuality, this was reduced to 16^o due to limitations imposed by the baffles. During operation the cameras operated remotely and unattended at a rate of 24 frames per hour with a maximum exposure duration of 150 s.

Although the two cameras operated synchronously, the duration for individual exposures of each camera was determined separately. The proper exposure duration of each data frame was determined by a small integrating photometer attached to the camera and utilizing the same basic field of view. The output of the photometer was recorded by the IECM data acquisition system at a sample rate of 30 per min. The photometer was used to terminate each exposure at a preset background level, adjustable over a range of 10^{-2} to 10^{-4} meter-candle-seconds set to correspond with film exposure parameters. The background brightness measured by the photometer was centered at 10^{-13} $B_\odot$ with a dynamic range of 10^{-3}.

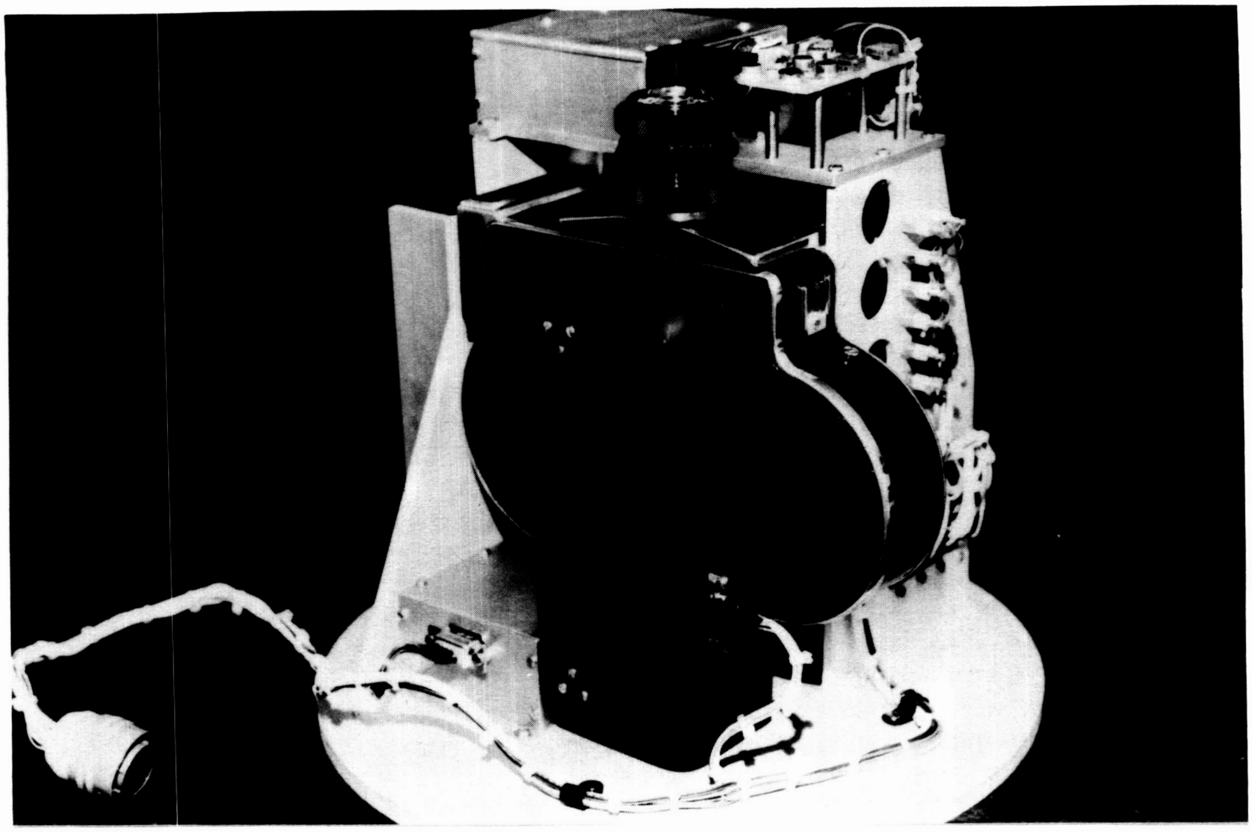
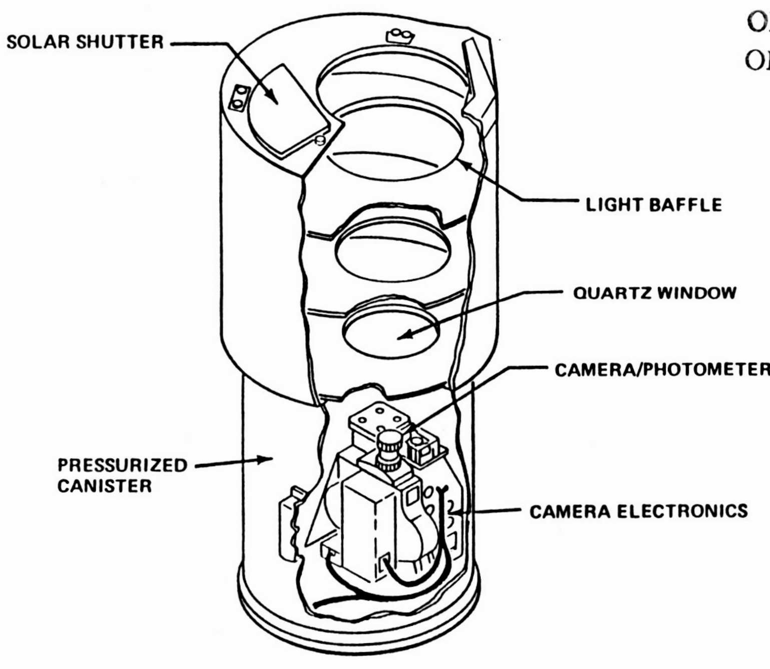


Figure 1. Photograph of the Camera/Photometer.



ORIGINAL PAGE IS
OF POOR QUALITY

Figure 2. Schematic of the Camera/Photometer indicating placement of the baffle, camera, and canister.

A small shutter controlled by associated timing and logic circuitry protected the photometer from intense light levels. Further protection was afforded the photometer from sudden increases of high-intensity brightness by design of the high voltage power supply which shut off the photometer voltage at excess dynode currents.

When activated, the camera utilized its film advance mechanism as a shutter in a chopping mode, operating once per second with an 80% open duty cycle. Thus, the continuous track of a moving particle was interrupted into a number of segments, each with a total exposure time of 800 ms. The motion of particles could therefore be isolated as shown in Figure 3. Due to the synchronous operation of the two cameras, simultaneous particle segments could be matched in the two fields of view. Distance was determined by measuring the parallax at each endpoint of a particle segment. Once the distance to each endpoint and the segment integration time were known, the particle velocities could be calculated. The segmentation of particle tracks also increased the number of particles available for size and velocity analyses by making it more likely that measurable particle endpoints appeared in the frame. This was particularly true at longer exposures.

Figure 3. An exposure of approximately 2 s obtained by one of the cameras showing contaminant particle tracks. The action of the chopper is clearly seen segmenting the trail. The different lengths of exposures are also delineated.

At the time of camera activation, an internal clock was set to zero, and time was reckoned from that point. Photographs were initiated continuously at 150-s intervals, regardless of the frame exposure duration. Upon termination of each exposure, the duration in seconds, as determined from the exposure counting circuit, and the elapsed operational time in minutes, from the elapsed time counter, was annotated onto the edge of the film. This was accomplished by a miniature seven-segment LED display, with the data focused onto the film by a folded optical system. As an alternative, exposure duration could also be determined from photometer data as recorded by the IECM data acquisition system, or often from the image itself from the appearance and number of particle segments.

With the shutter in the chopper mode, advancing the film to the next frame resulted in an added momentary exposure (0.1 s). This short exposure which occurred at the end of the overall frame exposure added a small track segment to the existing particle trails and thus was useful in determining the direction of particle motion. It was also beneficial in obtaining data during water dumps and other events with heavy particle concentrations that would normally be inhibited by high light levels.

The selection of a 16-mm photographic film for use by the cameras required consideration of thermal response, energy threshold, granularity, and shelf-life, among other factors. The ability to detect small particles was also of considerable importance. It was found that Kodak Double-X film, Type 7222, could allow exposures to approximately 10^{-2} erg cm^{-2} with good detective quantum efficiency. Thus, more of the 150-s frame period could be utilized for active observation while maintaining a small particle detection capability. A higher speed film such as Type 2485 limits the exposure to about 10 s for peak detection efficiency. Since the detective quantum efficiency curve falls off relatively rapidly from its maximum, it is desirable to shift the curve to longer exposures. This can be accomplished with the use of a slower film such as Double-X which also has the added benefit of greater resolution and less granularity when compared to higher speed films.

III. RESULTS

The Camera/Photometer was flown as part of the IECM on the STS-2, -3, -4, and -9 (Spacelab 1) missions. During these missions the IECM was located at the aft end of the payload bay. The optical axis of the cameras pointed directly out of the payload bay (along the -Z axis in the Orbiter coordinate system; see Figure 4). A total of 378 hours of observations were collected by the experiment on the four missions with a total of 18,000 frames of data recorded by the two cameras [11]. Many of these frames were obtained during nighttime passes or were light-saturated during the daytime due to reflections or to low

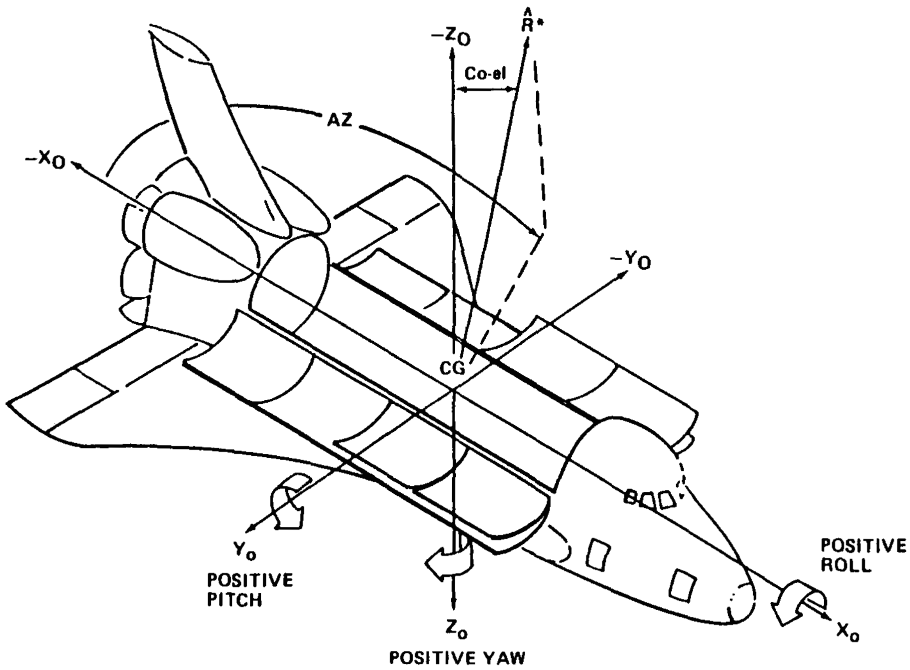


Figure 4. Orbiter body coordinate system defining body axes and angles of azimuth and co-elevation.

co-elevation angles of the Sun or bright Earth. For these reasons they were not usable for contamination measurements. Contaminant particles could only be detected when they were sunlit and could be contrasted against a relatively dark background. This occurred (1) during sunlit passes when the Orbiter -Z axis was directed to a stellar background away from the Sun and bright Earth, and (2) during that portion of the orbit lying between the terrestrial terminator and spacecraft sunrise (or sunset) with the -Z axis directed toward the dark Earth. During the four missions, contamination was detected under these conditions on over 1,800 data frames, or approximately 10 % of the total. A listing of all the contamination frames from all four missions is found in Appendix A. The list presents for each camera the frame number, the Mission Elapsed Time (MET) that the exposure began, the orbit number during which the exposure was made, the exposure duration, and the number of particles observed.

Examples of some of the types of contamination observed are shown in Figures 5-8. Figure 5 shows the typically heavy contamination observed during a water dump. The photograph with approximately a 1-s exposure was obtained during the STS-4 mission. Figure 6 is a 10-s exposure obtained from STS-2 and shows two populations of particles, those with horizontal motion

ORIGINAL PAGE IS
OF POOR QUALITY

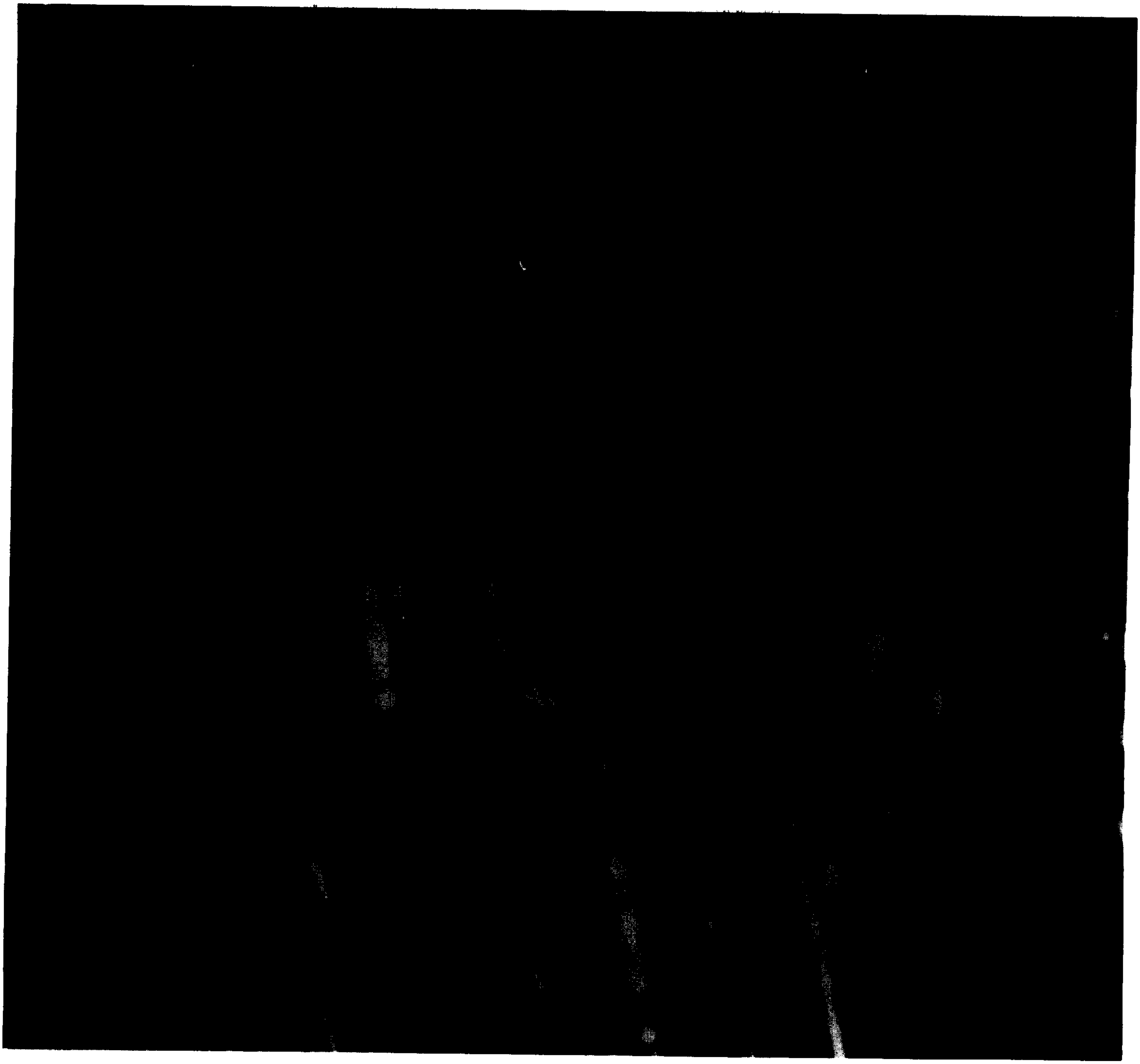


Figure 5. Example of contamination observed during a water dump seen during STS-4. The duration of the exposure is approximately 1 s.

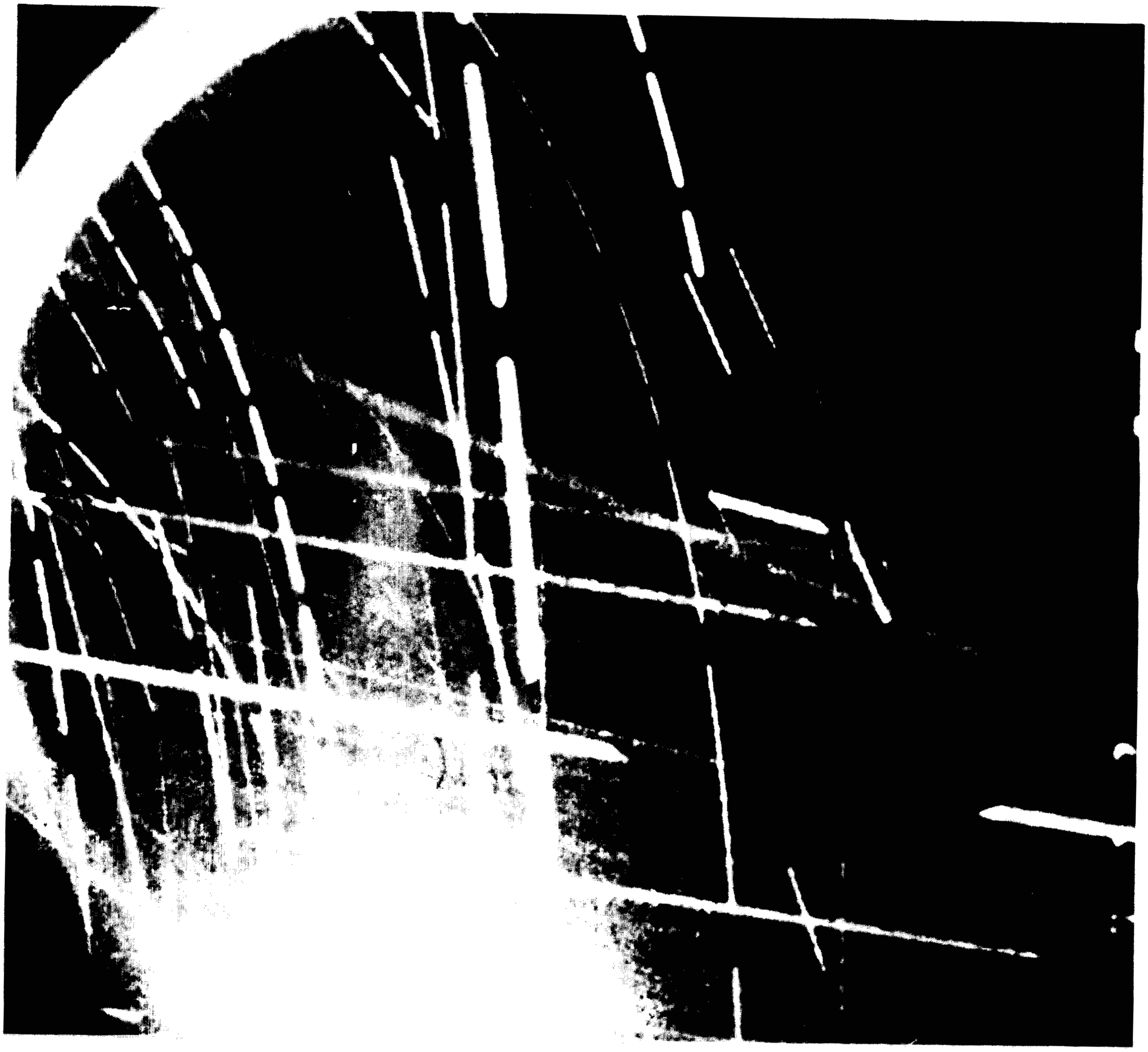


Figure 6. Example of early mission contamination seen during STS-2. Two streams of particles are evident. Particles nearby are moving horizontally, while more distant particles are seen with a "vertical" motion. A number of stars can also be seen in the photograph.

ORIGINAL PAGE IS
OF POOR QUALITY

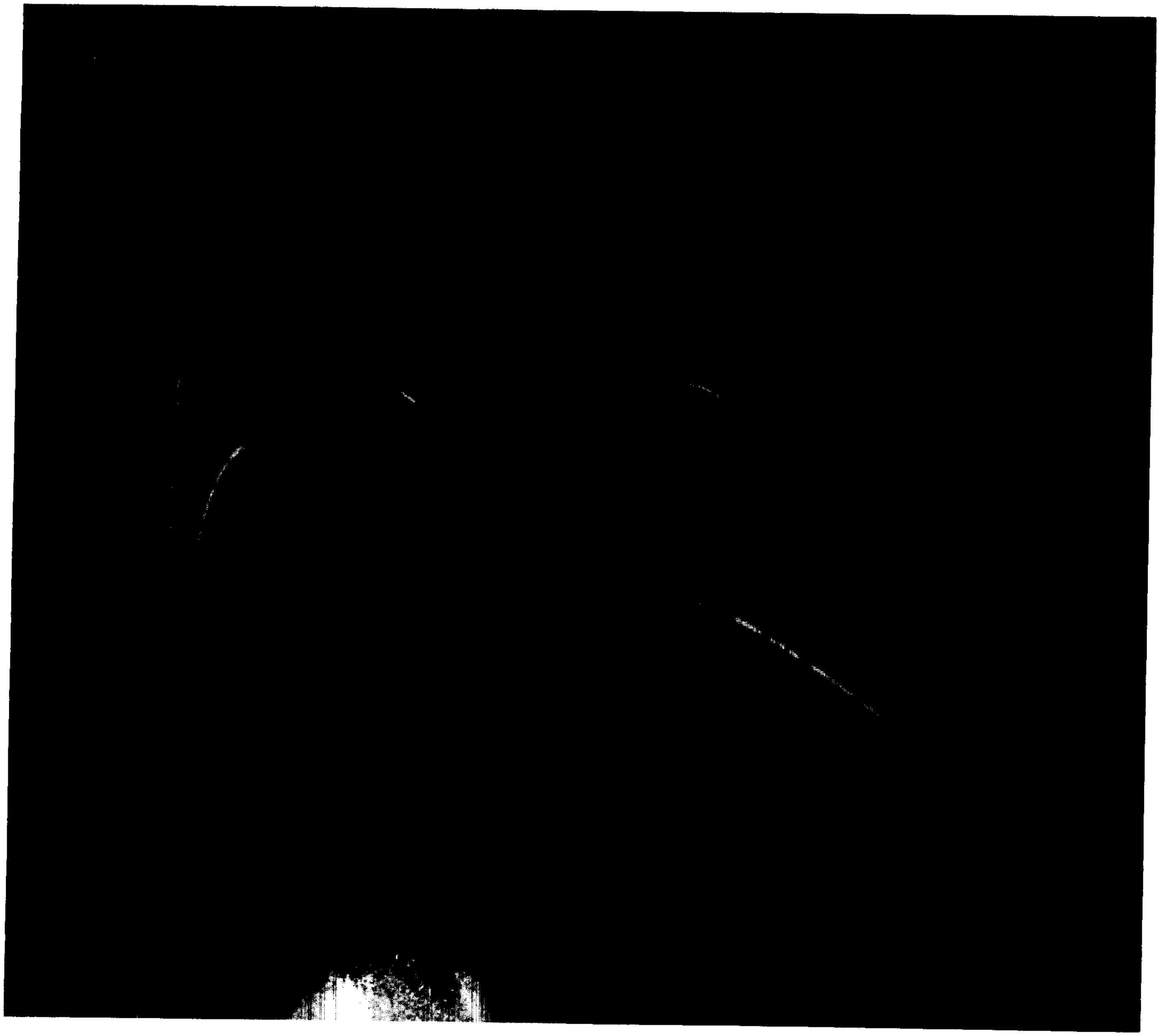


Figure 7. Example of contamination seen during the early portions of STS-2. The curvature of particle tracks appears to be due to the effects of the velocity vector of the spacecraft.

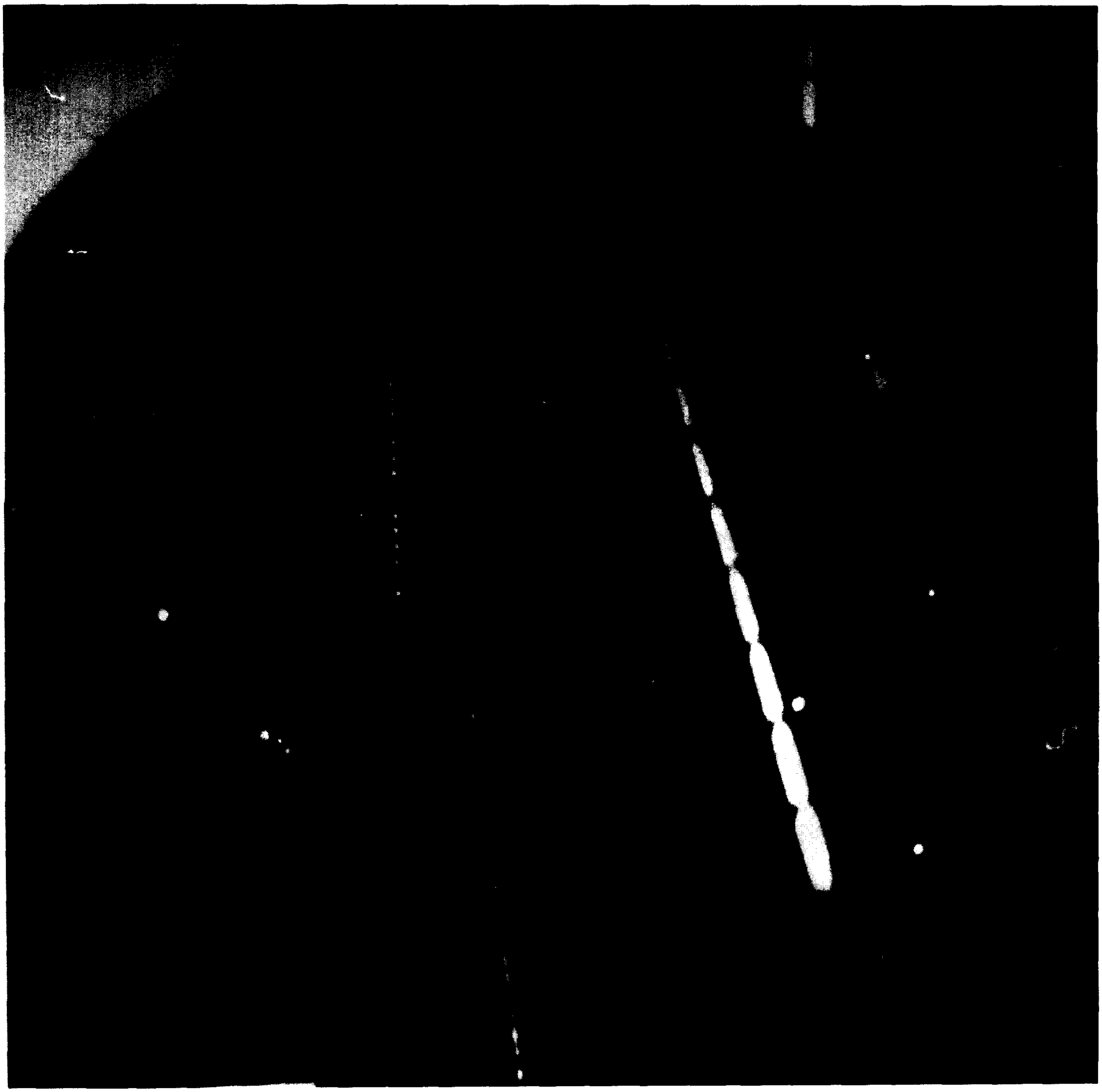


Figure 8. Striking example of particles seen during STS-4 moving away from the spacecraft into its shadow. Two particle tracks are resolved into a series of dots showing the effects of rotation.

and those with a curved vertical motion. The differences point to various origins of the particles. Shorter tracks produced by stars moving toward the upper left may also be seen. The curvature of particle tracks is not due to shuttle rotation, but appears to be caused by the particles aligning themselves with the velocity vector of the Orbiter due to drag from the residual atmosphere. This effect is more clearly shown in Figure 7 in a 4-s exposure from STS-2. The particle tracks may be seen to bend sharply, while the motion of the Orbiter may be discerned from the smeared images of clouds in the background and the tracks toward the center of the photograph produced by small terrestrial cities. Figure 8 shows another photograph obtained during the STS-4 mission. The photograph with an exposure of 10 s displays particles, some of which are rotating, moving away from the Orbiter into the Earth's shadow. Figures 5-8 all show relatively heavy concentrations of particles. More typical (but less dramatic) were photographs with many fewer particles or with none at all.

The data from all contamination frames sufficed to determine the general occurrence of particulate contamination, and a number of statistical studies have been performed on the particles comprising this comprehensive sample. For particle sizes and velocities, however, several other criteria must be fulfilled, and the mass of data capable of being analyzed is sharply reduced.

The measurement of the total velocities of particles requires information on both the transverse and radial components of the velocity vector. Transverse velocity is measured from the change per unit time in x-y position as recorded from a digital map of the image. Radial velocity is determined from the change per unit time in particle distance to camera. Distances are calculated from the parallaxes of particle segment endpoints, the exposure duration of the segment determining the intervening time of flight. Particle sizes are determined by converting the grayscales of the digitally-formatted image to film density values and relating these to the light energy deposited by the particle at a given distance and solar co-elevation angle. This is further discussed in Section IV.

In order to determine accurate sizes and total velocities, the particle must be recorded by both cameras. In this way the parallaxes, and hence distance, to each particle may be calculated. With the cameras separated by 40 cm, a minimum parallax of 4 arc min corresponding to a one pixel shift could be detected. This translated to an observational limit to particle distances of 300 m. The errors incurred at such distances are extremely large, however, and it was necessary to limit the maximum distance at which sizes and velocities would be calculated to 50 m. Also, while it is theoretically possible to measure the size of a nearby particle observed with a single camera by measuring the image diameter (See Section IV), the effects of image brightness on image diameter must also taken be into consideration, and the resulting calculations are more difficult and considerably more uncertain. Another criteria pertains to the length of exposure. In general, the longer the particle track in a given frame, the less error there will be in both velocity and size calculations. Not only are endpoints more accurately determined, but resulting errors in measurements are often less significant. In those cases in which the total exposure was caused following the annotation of timing information on the film, e.g., during water dumps or periods of extremely high particle concentrations, the particle segments are 0.1 s long. In most cases these exposures are too short for accurate measurements of velocity or size.

In addition to these criteria, a number of other factors were required in order to make size and velocity measurements. These included the following: (1) both endpoints of the segment had to be recorded by each camera; and (2) the contrast between particle and background was sufficient for the measurement to be made along the entire length of the track segment. In a number of cases, the particle could be visually discerned, but grayscale measurements along the track were often at background levels leading to an underestimation of size values. Finally, (3) two segments of at least one particle track had to be visible in the data frame. Although camera operation was synchronous, some variations were observed in the initiation time of the exposures. Thus, the first segments appearing in an exposure were not necessarily 0.8 s long, nor were they necessarily of equal length as observed by the two cameras. If these segments were to be used at all for velocity or size calculations, their ratio to known exposures must be calculated. These were provided by the appearance of additional segments (each of 0.8 s) in the fields of view.

IV. THEORETICAL ANALYSIS

Particle sizes may be determined from a consideration of the light energy delivered to the film plane. The energy deposited for a particle track segment may be written:

$$\varepsilon_n = \bar{E} \cdot A_f = \frac{\sum_{i=1}^{N} E_i}{N} \cdot N\, A_R = A_R \sum_{i=1}^{N} E_i , \qquad (1)$$

where $\bar{E}$ is the average exposure value taken over the image segment of area A_f, E_i is the exposure value of a single resolution element of area A_R, and N is the number of resolution elements comprising A_f. Since, by definition,

$$\bar{E} = \bar{I}_f \cdot t, \qquad (2)$$

where $\bar{I}_f$ is the illuminance received at the film plane and t is the exposure time of the segment, ε_n may also be written:

$$\epsilon_n = \bar{I}_f \cdot A_f \cdot t = \Phi_f \cdot t, \tag{3}$$

where Φ_f is the flux of light from the particle reaching the film plane. In addition,

$$\Phi_f = I_s A_D T, \tag{4}$$

where I_s is the illuminance from the particle received by the camera with lens aperture area A_D modified by the transmission factor T of the lens.

The illuminance of sunlight scattered from the particle and received by the camera lens is

$$I_s = I_\odot \frac{1}{r^2} \left(\frac{d\sigma}{d\Omega}\right)_\theta, \tag{5}$$

where $I_\odot$ is the illuminance of sunlight incident on the particle at a distance r from the camera determined stereoscopically, and $(d\sigma/d\Omega)_\theta$ is the scattering cross section of the particle. The scattering cross section at angle θ has been approximated to

$$\left(\frac{d\sigma}{d\Omega}\right)_\theta = \pi s^2 \frac{2K}{3\pi^2} (\sin\theta - \theta \cos\theta), \tag{6}$$

where the particle is assumed to be a Lambertian sphere of radius s and albedo K [12]. Assuming an albedo of unity and combining equations (3), (4), (5), and (6),

$$\epsilon_n = I_o A_D T t \frac{1}{r^2} \frac{2s^2}{3\pi} (\sin\theta - \theta \cos\theta) \tag{7}$$

While the distances for most particles may be determined stereoscopically, a number of particles are close enough to the instruments that their images are recorded by one camera only. In this case the particle will be de-focused to measurable size and the diameter of the focal plane image d_f, can be derived from geometric principles, such that

$$d_f = d_A \frac{F}{r} \frac{(1 - r/r_o)}{(1 - F/r_o)} \tag{8}$$

where d_A is the lens aperture diameter, F is the camera focal length and r_o is the distance to which the camera is focused. For $r_o = \infty$, the expression reduces to

$$d_f = d_A \frac{F}{r} \tag{9}$$

and the substitution for r can be made in equation (7).

V. ANALYSIS PROCEDURES

Flight data from the experiment was received in two forms: (1) film from the camera, and (2) digitally-reproduced PCM data of the photometer output from the IECM Data Acquisition System. In addition, temperature sensors attached to the cameras indicated the approximate maximum temperature reached at the camera position during each particular mission. This gave some indication of expected fogging and film degradation. Sensitometry step wedges placed at the beginning and the end of the film were used for calibration purposes in determining the relationship between film density and exposure (i.e., the D log E curves).

The flight film was processed at the Johnson Space Center. and optimized for environmental conditions. Both negative and positive copies of the film were made for viewing purposes. Preliminary analyses were conducted by running the film through a stop-frame motion picture projector on a frame-by-frame basis. Each photograph was appropriately logged, the extent of observed contamination was noted, and comments regarding the frame were made. From these data were drawn various statistical studies and overall contamination evaluations. Selected frames of the flight film were then digitized to computer-readable format using a Perkin-Elmer PDS 1010A microdensitometer. This unit measures optical densities ranging in values from 0 to 5 with an accuracy of $\pm$0.01. These values are then converted to 12-bit pixels capable of being stored on magnetic tape. Optical densities were measured through a 25 x 25 micron aperture and scanned over a data frame with a step size of 20 microns. The resulting frame consisted of an array of 512 by 512 pixels. In addition to the image data, coordinate and file identification data were placed into each tape record. The film step wedges were also scanned to construct preliminary D log E curves.

The data collected on magnetic tape were processed to obtain detailed analyses of individual particle parameters. This was accomplished using the Video Image Processing System (VIPS) at the Space Science Laboratory of the Marshall Space Flight Center [13]. The data were transferred from tape to computer hard disc, with the restored images subsequently displayed on video monitors for analysis.

A schematic representation of the VIPS and peripheral units is shown in Figure 9. The core of the system is a Hewlett-Packard Series 500 desktop computer with 2 Mbyte RAM memory and a 9.8-Mbyte Winchester disc. A color graphics capability provides a 512 x 390 pixel image in as many as 16 colors. A high-speed 65 Mbyte hard disc is used to save and retrieve digitized frames. It can store approximately 250 frames of data in 512 x 512 x 8-bit pixel format. The data can be recalled from disc memory and displayed by one of two image memories on associated video monitors. Hard copies can be made of the data while it is in video format using a video hard copy unit. A graphics tablet used in conjunction with the computer provides remote user interaction with the VIPS by allowing the user to select program options or image positional data with a stylus pen. Grayscale values of the image may be read directly from the CRT or printed on a line printer. Color contours can be displayed on the CRT with hard copies made using a graphics plotter. The computer and its peripherals are connected using an IEEE-488 interface.

Software developed for use with the IECM data provides an interactive basis for the user to view selected frames, review current data, conduct particle analyses, and store new information. The basis of the analysis software is the Particle Analysis (PARTAN) program, the basic menu of which is shown in Figure 10. As noted in the figure, six options are presented to

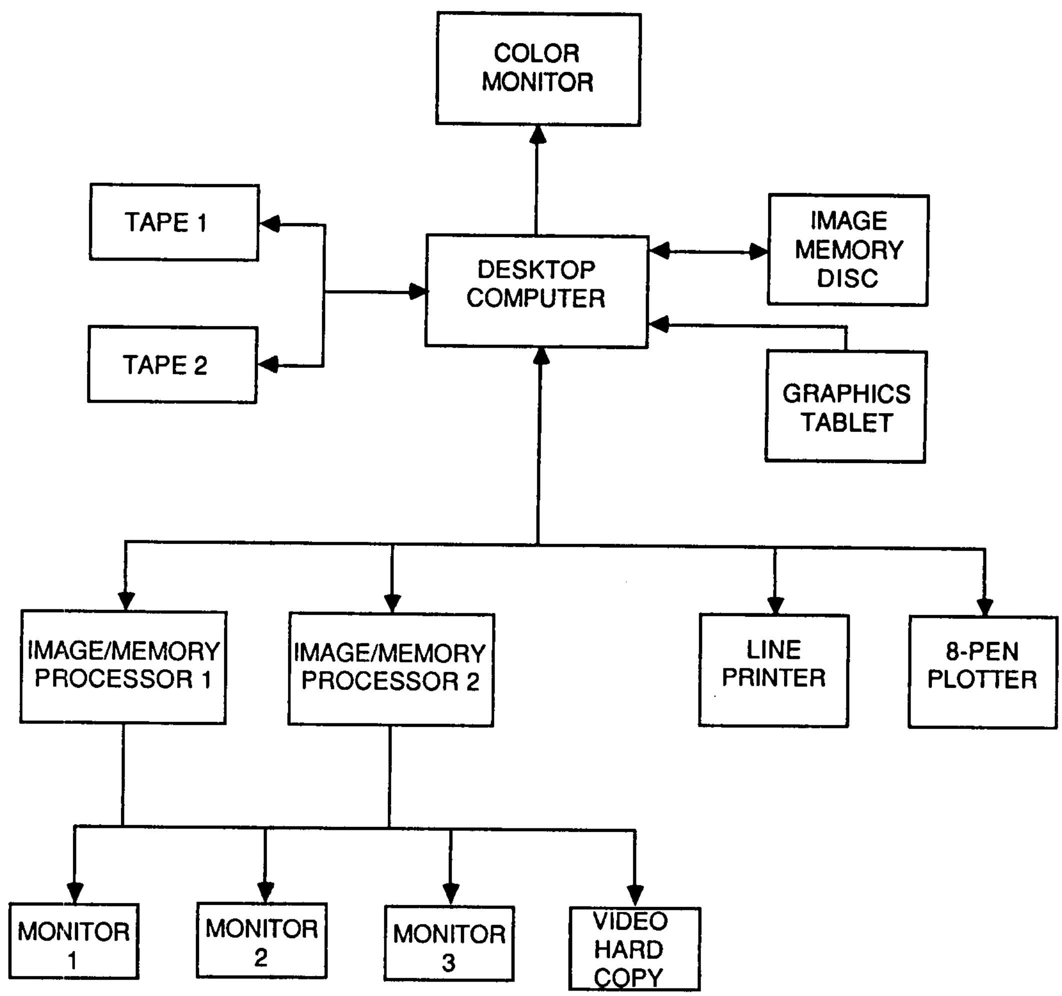


Figure 9. Schematic of the Video Image Processing System.

the user. These options include the Particle Data Acquisition Routine, Image Transfer Routine, Cursor Routine, Retrieval of Existing Particle Data, D log E Selection Routine, and Flag/Remove Particle File Routine, respectively.

Interactive PARTAN

1) Particle Data Acquistion Routine
2) Image Transfer Routine
3) Cursor Routine
4) Retrieve Existing Particle Data
5) Density vs Log Exp Curve Selection Routine
6) Flag/Remove Particle File

Figure 10. Basic menu of PARTAN showing the options available to the user.

The Image Transfer Routine (option 2) allows the transfer of image data from one storage medium to another. These mediums include two tape drives, hard disc memory, two image arrays located in computer memory, and an image memory/processor. All of the digitized data frames are stored onto hard disc, and an index of these frames is available to the user from which he may make an image selection. At any given time, as many as two such images can be transferred and simultaneously stored in computer memory. This allows a sequential transfer of the data to the image memory/processor and viewing on associated video monitors. Thus, the user may view the corresponding data collected by each IECM camera at any particular MET. The resulting images may also be enhanced by the processor for easier viewing of faint particle tracks, although all quantitative data analysis is conducted in a non-enhanced mode. A submenu of this option is displayed in Figure 11.

The Cursor Routine, option 3 of the main program, allows the x-y position and grayscale of any picture element to be displayed on the computer terminal. A blinking cursor can be positioned manually from the keyboard or with the use of a stylus pen on the graphics tablet to any point of an image displayed by the image memory/processor. Once the cursor is positioned, the computer terminal displays a block of 13 x 13 pixels centered about the current cursor location, as shown for a stellar image in Figure 12. Contour lines at intervals of 10 grayscale values from the peak value are superimposed on the image. In addition, the average grayscale value of the pixel block is displayed along with the standard deviation of values within the block.

The Retrieval of Existing Particle Data Routine displays the size, velocity, distance, or other existing data for any particle

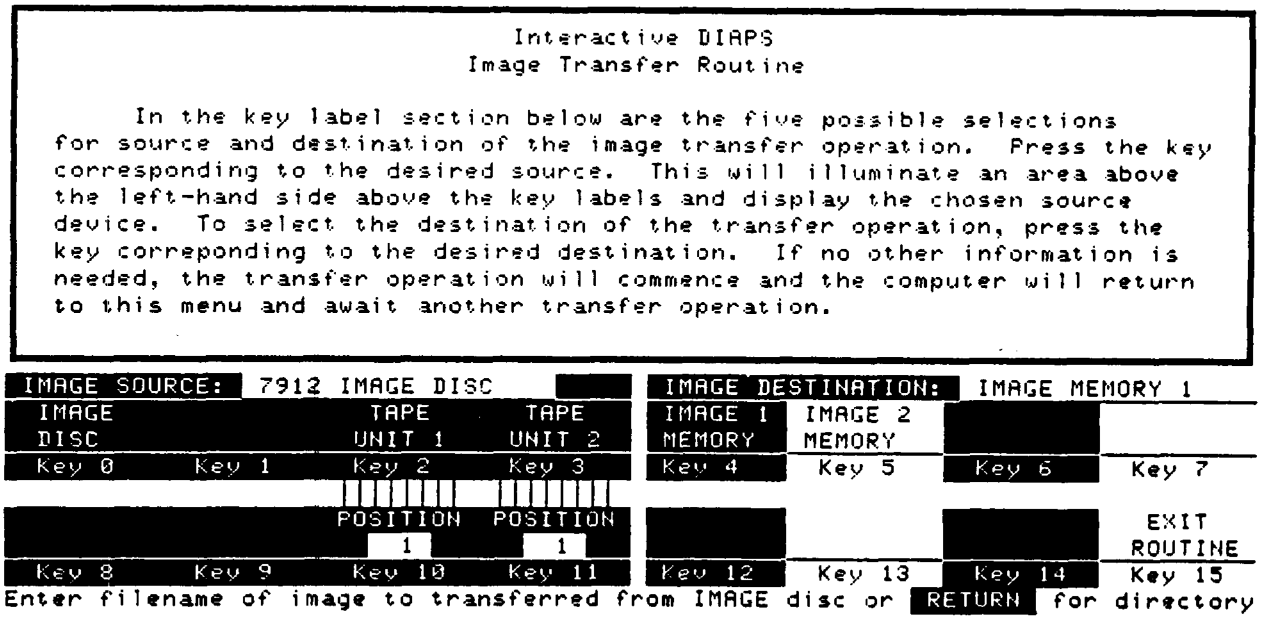


Figure 11. Submenu of the Image Transfer Routine of the PARTAN program.

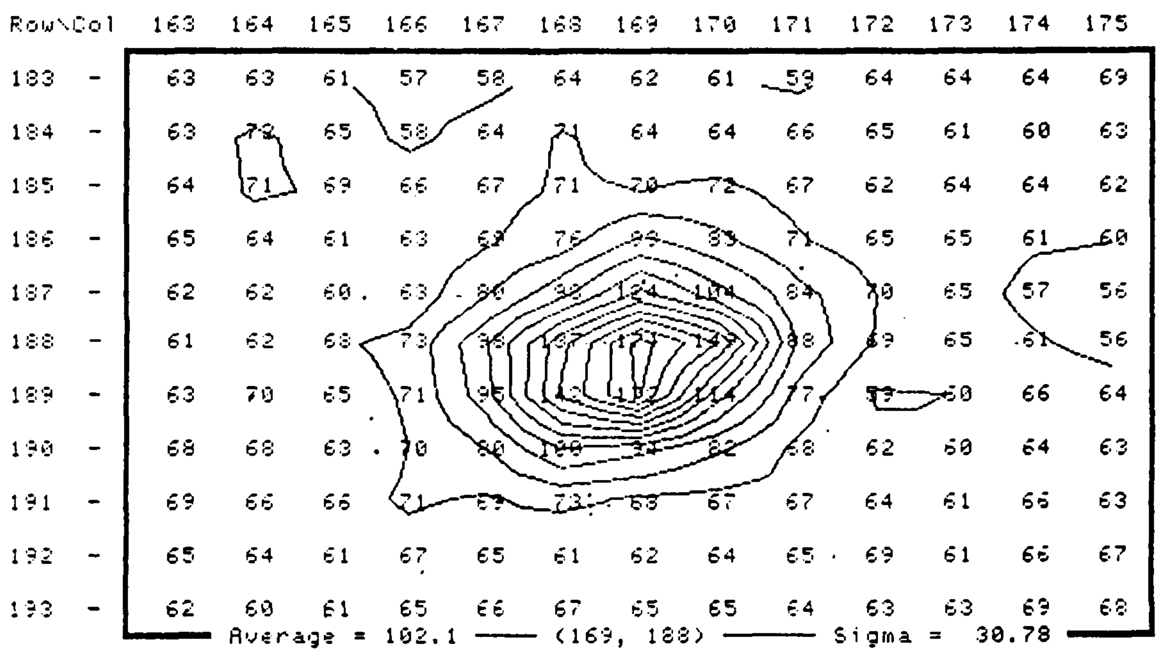


Figure 12. A contoured block of a digitized star image from one of the IECM data frames as presented by the Cursor Routine of the PARTAN program.

ORIGINAL PAGE IS OF POOR QUALITY

of interest selected by the user. The format displayed is essentially the same as that utilized in the Particle Data Acquisition Routine shown below.

The Density vs Log Exp Curve Selection Routine allows the user to select any of the density versus log exposure (D log E) curves for the films used on the different missions. These data in the form of a look-up table are input to particle size calculations.

The Flag/Remove Particle File Routine is used to drop from the active list of particles any data that fail to meet established criteria. For example, particles more distant than 50 m are not used in the active particle list since such distances are subject to considerable error. If the analysis of a selected particle shows such a distance, these data are flagged, and though still held in memory, they will not appear in particle listings.

The Particle Data Acquisition Routine provides the main user program, and it is with this option that the size and velocity analysis of particles is accomplished. The submenu of this routine is shown in Figure 13. The analysis of a particle requires that the data frame containing the particle be displayed by the memory/processor. With the proper D log E information transferred to memory, various required parameters are input into the computer. Positional endpoints of particle segments are determined with the use of the cursor program for calculation of particle parallax and hence distance. Registration between the data frames of camera 1 and camera 2 is determined from a comparison of background stars and from the relative placement of film sprocket holes. The horizontal difference between the two frames caused by registration errors is input as the "Horizontal Shift."

The background level near the particle is determined from the mean value of grayscales within a 5 x 5 block using the cursor program. Exposure times are determined from integrated photometer data or from particle segment lengths. Given this information, and utilizing the Scan Particle key, the computer program determines the distance to the particle at each endpoint, the transverse, radial, and total velocities of the particle, and its size. The latter is determined by a scan of the grayscale data between the two endpoints. The width of the scan can be set manually with the Particle Width key in order to encompass the complete particle image. Default value for the width is set at 3 pixels. In this manner the total amount of light energy above background deposited by the particle may be determined along the particle segment.

In a few cases it is advisable to modify the grayscale data along the particle segment before the size calculation is made, for example, with crossing particle tracks, nearby stars, etc.

ORIGINAL PAGE IS
OF POOR QUALITY

Interactive PARTAN
Data Acquistion Routine
Current Parameters for particle 9-3175- 1

Revision 3.0

Camera	Endpoint 1	Endpoint 2
1	(153.00,186.00)	(153.00,132.00)
2	(107.50,182.00)	(109.00,129.00)

Solar coelevation	=	133.2 degrees
Particle width	=	3.00 pixels
Horizontal shift	=	+.75 pixels

Camera	Backgrnd	Exposure	Distance (m) Endpt1	Endpt2	Velocity (m/s) Radial	Trnvse	Total	Size (microns)
1	65.0	.80	7.75	8.02	.34	.61	.70	32.40
2	60.0	.80	7.69	7.96	.34	.59	.68	25.40

CAMERA 1 ENDPOINT 1	CAMERA 1 ENDPOINT 2	CAMERA 1 BACKGROUND	EXPOSURE TIME	SCAN PARTICLE	CURSOR ROUTINE	PARTICLE IDENTIFIER	ANALYZE PARTICLE
Key 0	Key 1	Key 2	Key 3	Key 4	Key 5	Key 6	Key 7
CAMERA 2 ENDPOINT 1	CAMERA 2 ENDPOINT 2	CAMERA 2 BACKGROUND	SOLAR COEL	PARTICLE WIDTH	STORE PARTICLE	HORIZONTAL SHIFT	EXIT ROUTINE
Key 8	Key 9	Key 10	Key 11	Key 12	Key 13	Key 14	Key 15

Currently displaying CAMERA 2

Figure 13. Typical particle data portrayed as part of the Particle Data Acquisition Routine of the PARTAN program. New data can be edited and stored for any particle.

these cases, the Scan Particle routine can be used to display the particle track with the data to be used for size calculations highlighted as shown in Figure 14. By using the cursor, data points can be added and subtracted from the scanned value, allowing substitutions of grayscale data for obviously incorrect values. The total energy value is amended with each change of grayscale and the size recalculated.

Final corrections are applied to the data to account for film reciprocity failure and intermittency effects. These effects predominantly affect the particles with the least apparent motion, hence writing speed of the particle, and thus shift the D log E curve to higher energies dependent upon the integration time of light on individual pixels. Due to the wide variation of observed integration times and writing speeds, a calibration of these effects required the analysis of a number of different star fields. Over 15 data frames consisting of both stationary fields with different integration times and moving star fields (with different angular velocities) were examined. Between 50 and 100 stars of known brightnesses were selected from each of these frames, and, using a variation of the PARTAN, magnitudes for the stars were first predicted from the amount of

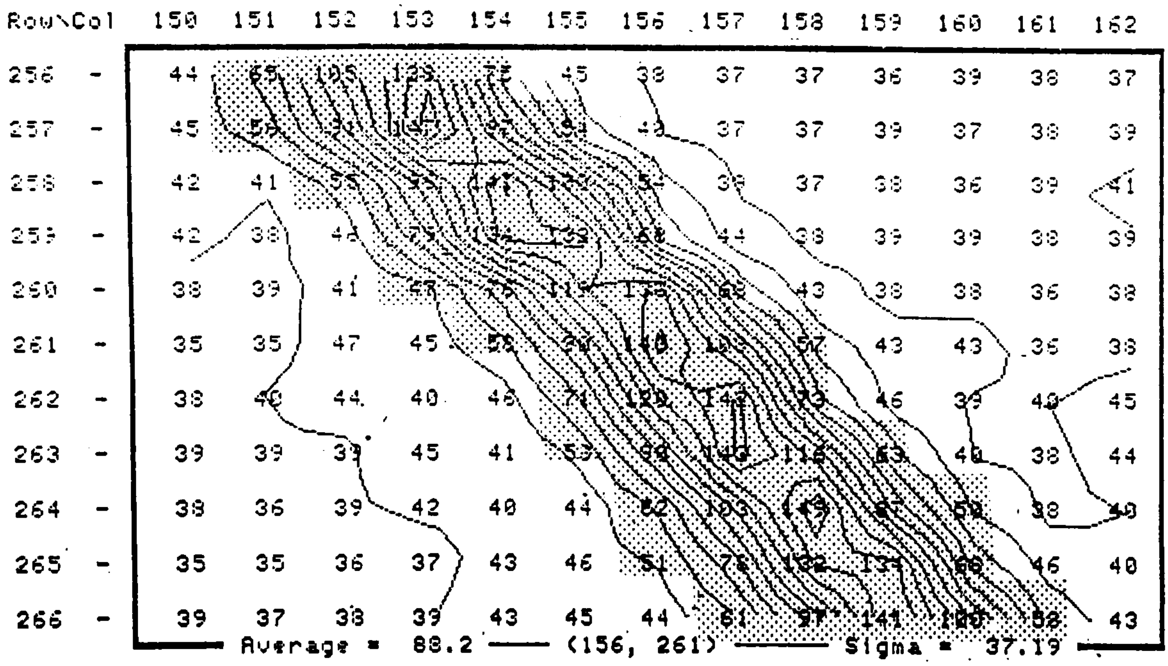


Figure 14. Example of a particle track as determined with the use of the Scan Particle routine in the Particle Data Acquisition Routine. Shaded areas are those points taken for the determination of the particle size.

energy comprising the stellar image and then compared with the known values. A distribution of errors, one of which is shown in Figure 15, was plotted for each frame. The mean error resulting from each frame was used in conjunction with that frame's integration time to determine the general relationship of error versus image integration time. In moving star fields, the writing speed of the image was used to determine the pixel integration time.

Once all the corrections were applied to the data, the resulting size and velocity data for the particle were stored on hard disc with a designation giving mission, data frame, and particle number for easy retrieval. A preliminary listing of the particle sizes and velocities is given in Appendix B. Nearly 270 particle velocities have been determined and are presented in this list, while sizes for approximately 230 particles are included. It is anticipated that further studies of these particles may produce refinements in this data, for example, in terms of film registration, etc. The number of particles used in the listing might also be expected to increase with the analyses of additional frames.

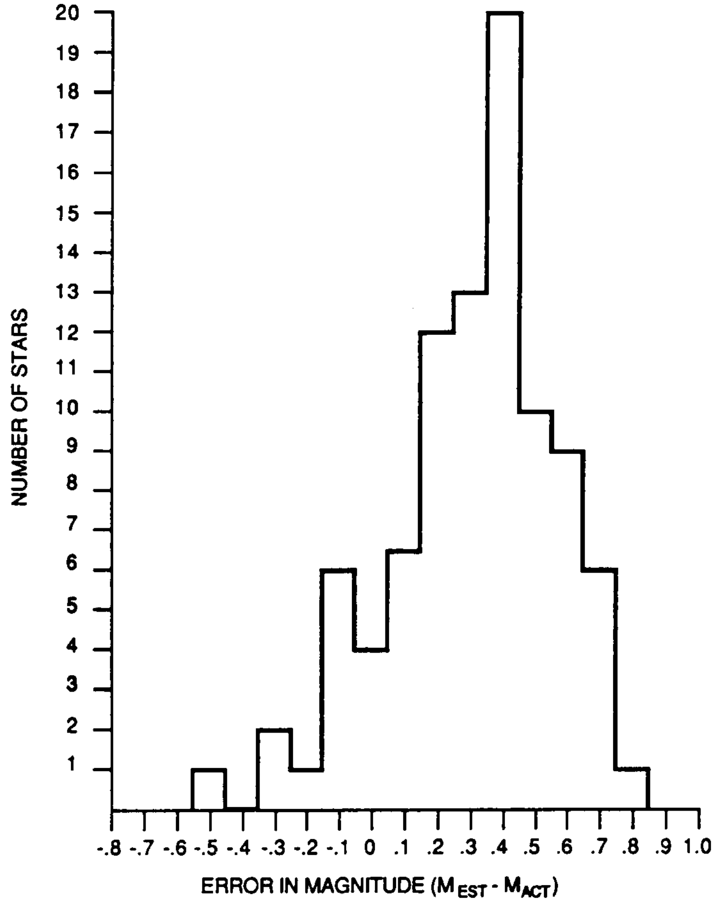


Figure 15. Typical example of error distribution of star magnitude between that predicted with the use of PARTAN and the actual magnitude as determined from the Smithsonian Star Catalogue.

REFERENCES

1. Simpson, J. P., and Witteborn, F. C., Appl. Opt., Vol. 16, 1977, pp. 2051-2073.

2. STS Payload Contamination Requirements Definition Group Report, NASA/Marshall Space Flight Center, Huntsville, AL, 1975.

3. Miller, E. R., and Decher, R., An Induced Environment Contamination Monitor for the Space Shuttle, NASA TM-78193, 1978.

4. Miller, E. R. (Editor), STS-2 Induced Environment Contamination Monitor (IECM) - Quick-Look Report, NASA TM-82457, 1982.

5. Miller, E. R., and Fountain, J. A. (Editors), STS-3 Induced Environment Contamination Monitor (IECM) - Quick-Look Report, NASA TM-82489, 1982.

6. Miller, E. R. (Editor), STS-2, -3, -4 Induced Environment Contamination Monitor (IECM) Summary Report, NASA TM-82524, 1983.

7. Miller, E. R., Update of Induced Environment Contamination Monitor Results. AIAA-83-2582-CP, AIAA Shuttle Environment and Operations Meeting, October 31-November 2, 1983.

8. Ehlers, H. K. F., Jacobs, S., Leger, L. J., and Miller, E. R., J. Spacecraft, Vol. 21, 1984, pp. 301-308.

9. Miller, E. R., Induced Environment Contamination Monitor - Preliminary Results from the Spacelab 1 Flight, NASA TM-86461, 1984.

10. Clifton, K. S., and Owens, J. K., Monitoring of Particulate Contamination and Background Brightness from IECM Based Instrumentation, Proceedings of the 10th Space Simulation Conference, Bethesda, MD, October 1978.

11. Clifton, K. S., and Owens, J. K., Appl. Opt., Vol. 27, 1988, pp. 603-609.

12. Naumann, R. J., Contamination Assessment and Control in Scientific Satellites, NASA TN D-7433, 1973.

13. Clifton, K. S., Benson, C. M., and Gary, G. A., A Digital Imaging Photometry System for Cometary Data Acquisition, NASA TM-86554, 1986.

APPENDIX A. CONTAMINATION DATA FRAMES

STS-2

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
5	2:36.5	2	4	>30	2	11	
6	2:39.0	2	2	>30	2	>30	
7	2:41.5	2	—	>30	—	19	
8	2:44.0	2	2	>30	2	>30	
9	2:46.5	2	—	>30	—	26	
10	2:49.0	2	—	20	—	28	
11	2:51.5	3	2	>30	—	>30	
12	2:54.0	3	—	>30	—	>30	
13	2:56.5	3	2	>30	—	>30	
14	2:59.0	3	2	>30	—	>30	
15	3:01.5	3	2	>30	—	>30	
16	3:04.0	3	—	>30	—	>30	
17	3:06.5	3	—	>30	—	>30	
18	3:09.0	3			—	>30	
27	3:31.5	3	4	>30	2	>30	
41	4:06.5	3	10	>30	2	21	
63	5:01.5	4	—	14	—	12	
77	5:36.5	4	—	4	—	1	
98	6:29.0	5	—	2	—	2	
99	6:31.5	5	4	1	—	1	
112	7:04.0	5	—	14	—	6	
134	7:59.0	6	4	18	2	17	
148	8:34.0	6	—	15	—	9	
170	9:29.0	7	—	3	—	1	
184	10:04.0	7	—	9	—	4	
206	10:59.0	8			—	3	
235	12:11.5	9	—	>30	—	>30	
236	12:14.0	9	—	>30			
237	12:16.5	9	—	>30			
238	12:19.0	9	—	>30	—	>30	
239	12:21.5	9	—	>30	—	>30	
242	12:29.0	9	6	>30	—	>30	
278	13:59.0	10			—	2	
327	16:01.5	11	—	2			
471	22:01.5	15	—	2	—	2	
529	24:26.5	17			—	1	
601	27:26.5	19	2	1			
672	30:24.0	21			—	1	
673	30:26.5	21	—	3			
980	45:59.5	31	—	1	—	1	
1021	47:42.0	33	2	7			

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
1022	47:44.5	33	12	9			
1023	47:47.0	33	6	2	—	7	
1024	47:49.5	33	4	5	—	3	
1025	47:52.0	33	4	>30	—	>30	
1026	47:54.5	33	2	>30	—	>30	
1027	47:57.0	33	1	>30	—	>30	
1057	49:12.0	34	2	1			
1058	49:14.5	34	—	1			
1060	49:19.5	34	2	1			
1061	49:22.0	34			—	1	
1062	49:24.5	34	2	1			
1063	49:27.0	34	2	2	—	1	
1064	49:29.5	34			—	1	
1065	49:32.0	34	—	4	—	1	
1066	49:34.5	34	—	2	—	2	
1067	49:37.0	34	6	2			
1068	49:39.5	34	—	2	—	2	

STS-3

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
3	2:04.5	2	10	>30			
17	2:39.5	2	—	1			
18	2:42.0	2	—	>30	—	>30	
38	3:32.0	3	18	9			
134	7:32.0	6	—	5			
140	7:47.0	6	—	2			
145	7:59.5	6	16	6	10	1	
160	8:37.0	6	52	3	42	3	
161	8:39.5	6	14	3	12	4	
162	8:42.0	6	2	3	2	2	
164	8:47.0	6	—	3			
165	8:49.5	6	—	1	—	1	
167	8:54.5	7	—	3	—	3	
169	8:59.5	7	—	5	—	3	
170	9:02.0	7	2	10	—	4	
171	9:04.5	7	—	2	—	3	
172	9:07.0	7	—	7	—	6	
173	9:09.5	7	—	5	—	2	
174	9:12.0	7	—	3	—	1	
175	9:14.5	7	—	3			
176	9:17.0	7	—	3	—	1	
181	9:29.5	7	4	2	2	2	
196	10:07.0	7	14	5	8	3	
197	10:09.5	7	4	1	—	1	
198	10:12.0	7	4	3	2	3	

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1		CAMERA 2		COMMENTS
			EXP	NUMBER OF PARTICLES	EXP	NUMBER OF PARTICLES	
199	10:14.5	7	4	3	2	3	
200	10:17.0	8	4	3	2	2	
201	10:19.5	8	4	2	2	1	
202	10:22.0	8	4	8	2	6	
203	10:24.5	8	2	9	4	11	
204	10:27.0	8	—	4	2	4	
205	10:29.5	8	—	3	—	1	
206	10:32.0	8	2	10	—	5	
207	10:34.5	8	—	4	2	6	
208	10:37.0	8	—	5	—	2	
209	10:39.5	8	—	2	—	2	
210	10:42.0	8	—	1	2	2	
211	10:44.5	8	—	3	2	4	
212	10:47.0	8			4	2	
213	10:49.5	8	2	1	2	4	
216	10:57.0	8			16	1	
231	11:34.5	8	24	3			
232	11:37.0	8	8	9	6	9	
233	11:39.5	8	8	5	6	5	
234	11:42.0	8	4	6	4	9	
235	11:44.5	8	8	4	6	5	
236	11:47.0	9	8	1	4	2	
237	11:49.5	9	4	1	—	1	
238	11:52.0	9	2	1	4	2	
239	11:54.5	9	—	1	2	1	
240	11:57.0	9			2	1	
241	11:59.5	9	—	2	2	4	
242	12:02.0	9	—	>30	—	>30	
244	12:07.0	9	—	1	2	1	
246	12:12.0	9			2	2	
248	12:17.0	9	4	1			
250	12:22.0	9	14	1	14	1	
268	13:07.0	9	10	3	8	2	
269	13:09.5	9			4	1	
270	13:12.0	9	8	2	4	6	
271	13:14.5	9	8	2	4	4	
272	13:17.0	10	6	1			
273	13:19.5	10	2	1			
274	13:22.0	10	2	1	2	1	
275	13:24.5	10	—	1	2	4	
276	13:27.0	10	—	2	—	3	
277	13:29.5	10	—	1	—	2	
278	13:32.0	10	—	1	—	1	
279	13:34.5	10	—	1	—	1	
280	13:37.0	10			2	2	
285	13:49.5	10			10	1	
303	14:34.5	10	10	1			
305	14:39.5	10			8	1	
306	14:42.0	10	8	1	8	1	
307	14:44.5	10			8	1	

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
308	14:47.0	11	6	1			
312	14:57.0	11	2	1	—	1	
314	15:02.0	11	2	2	—	2	
316	15:07.0	11	2	2	—	1	
317	15:09.5	11	2	2			
341	16:09.5	11	8	1			
343	16:14.5	12			8	4	
346	16:22.0	12	2	1	4	1	
348	16:27.0	12	—	2	2	1	
377	17:39.5	12			10	1	
378	17:42.0	12			8	2	
379	17:44.5	13	6	1	4	1	
381	17:49.5	13			2	1	
382	17:52.0	13	2	1	2	1	
384	17:57.0	13	—	1			
386	18:02.0	13	—	1			
410	19:02.0	13	22	1	26	1	
413	19:09.5	13			6	1	
414	19:12.0	14			2	1	
431	19:54.5	14	22	1	18	1	
457	20:59.5	15	2	1	2	1	
460	21:07.0	15	2	1			
486	22:12.0	16	2	1	2	1	
491	22:24.5	16	—	2	2	1	
493	22:29.5	16	—	1	—	1	
520	23:37.0	16	6	1			
524	23:47.0	17			2	1	
526	23:52.0	17	—	1	—	1	
546	24:42.0	17	32	2	32	2	
564	25:27.0	18	2	1			
569	25:39.5	18	4	1	2	1	
589	26:29.5	18	10	1	6	1	
598	26:52.0	19	2	1	2	1	
642	28:42.0	20	4	1			
702	31:12.0	22	2	1			
743	32:54.5	23	—	1			
751	33:14.5	23	10	1			
804	35:27.0	24	2	>30	—	>30	
814	35:52.0	25	—	5			
838	36:52.0	25	36	1	30	1	
840	36:57.0	25	—	12			
1074	46:42.0	32	6	25	—	25	

STS-4

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
43	3:36.5	3	—	>10			
59	4:16.5	4	—	>30			
94	5:44.0	5	—	>30			
95	5:46.5	5	—	>30			
96	5:49.0	5	—	>30			
97	5:51.5	5	—	>30			
98	5:54.0	5	—	>30			
99	5:56.5	5	—	>30			
100	5:59.0	5	—	>30			
101	6:01.5	5	—	>30			
102	6:04.0	5	—	>30			
103	6:06.5	5	—	>30			
104	6:09.0	5	—	>30			
131	7:16.5	6	4	>30			
132	7:19.0	6	2	>30			
133	7:21.5	6	—	>30			
134	7:24.0	6	—	>30			
135	7:26.5	6	—	>30			
137	7:31.5	6	—	>30			
138	7:34.0	6	—	>30			
141	7:41.5	6	—	>10			
142	7:44.0	6	—	>10			
143	7:46.5	6	—	>30			
145	7:51.5	6	—	>30			
146	7:54.0	6	—	>30			
147	7:56.5	6	—	>30			
148	7:59.0	6	2	>30			
149	8:01.5	6	2	>30			
150	8:04.0	6	4	>30			
151	8:06.5	6	—	>30			
167	8:46.5	7	2	>30			
185	9:31.5	7	2	13			
186	9:34.0	7	6	>30			
187	9:36.5	7	28	>30			
188	9:39.0	7	28	2			
203	10:16.5	8	2	>30			
221	11:01.5	8	2	11			
222	11:04.0	8	6	15			
223	11:06.5	8	10	26			
224	11:09.0	8	4	12			
239	11:46.5	9	10	>30			
258	12:34.0	9	4	5			
259	12:36.5	9	18	15			
260	12:39.0	9	26	14			
276	13:19.0	9	8	>30			

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
294	14:04.0	10	2	5			
295	14:06.5	10	16	6			
296	14:09.0	10	22	11			
312	14:49.0	10	6	>30			
331	15:36.5	11	10	12			
332	15:39.0	11	18	7			
348	16:19.0	12	10	>30			
366	17:04.0	12	—	2			
367	17:06.5	12	8	2			
368	17:09.0	12	18	15			
384	17:49.0	13	6	>30			
402	18:36.5	13	4	10			
403	18:39.0	13	14	10			
404	18:41.5	13	14	10			
419	19:19.0	14	22	>30			
420	19:21.5	14	6	17			
441	20:11.5	14	2	5			
477	21:41.5	15	—	4			
565	25:21.5	18	10	>30			
566	25:24.0	18	—	22			
567	25:26.5	18	—	15			
568	25:29.0	18	—	4			
569	25:31.5	18	—	1			
570	25:34.0	18	—	2			
572	25:39.0	18	—	1			
573	25:41.5	18	—	1			
574	25:44.0	18	—	2			
575	25:46.5	19	—	4			
576	25:49.0	19	—	5			
577	25:51.5	19	—	4			
586	26:14.0	19	—	2			
601	26:51.5	19	10	16			
602	26:54.0	19	2	7			
603	26:56.5	19	—	13			
604	26:59.0	19	—	4			
606	27:04.0	19	—	1			
608	27:09.0	19	—	4			
610	27:14.0	19	—	1			
611	27:16.5	19	—	2			
612	27:19.0	19	—	5			
613	27:21.5	19	—	3			
614	27:24.0	19	—	6			
637	28:21.5	20	10	9			
638	28:24.0	20	2	2			
639	28:26.5	20	—	4			
640	28:29.0	20	—	3			
643	28:36.5	20	—	2			
647	28:46.5	20	—	1			
648	28:49.0	20	—	2			
649	28:51.5	20	—	1			

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
673	29:51.5	21	34	18			
674	29:54.0	21	10	18			
675	29:56.5	21	2	15			
680	30:09.0	21	—	2			
681	30:11.5	21	—	3			
686	30:24.0	21	—	3			
710	31:24.0	22	—	>30			Water dump
711	31:26.5	22	2	>30			Water dump
712	31:29.0	22	2	>30			Water dump
713	31:31.5	22	4	>30			Water dump
714	31:34.0	22	2	>30			Water dump
715	31:36.5	22	2	>30			Water dump
716	31:39.0	22	2	>30			Water dump
717	31:41.5	22	2	>30			Water dump
718	31:44.0	22	2	>30			Water dump
719	31:46.5	22	—	>30			Water dump
999	43:26.5	30	—	5			
1061	48:38.5	33	—	1			
1062	48:41.0	33	6	7			
1063	48:43.5	33	10	7			
1064	48:46.0	33	10	15			
1065	48:48.5	33	10	13			
1082	51:46.5	35	6	1			
1083	51:49.0	35	4	17			
1117	53:14.0	36	22	1			
1118	53:16.5	36	24	5			
1119	53:19.0	36	18	8			
1120	53:21.5	36	28	4			
1154	54:46.5	37	22	3			
1155	54:49.0	37	28	2			
1156	54:51.5	37	32	6			
1172	55:31.5	38	8	12			
1207	57:01.5	39	10	15			
1243	58:31.5	40	8	12			
1279	60:01.5	41	8	15			
1280	60:04.0	41	4	2			
1315	61:31.5	42	8	6			
1388	64:34.0	44	6	5			
1408	65:24.0	44	2	>30			Water dump
1554	73:35.5	50	10	8			
1555	73:38.0	50	4	7			
1556	73:40.5	50	2	13			
1557	73:43.0	50	—	6			
1647	77:25.5	52	2	>30			Water dump
1648	77:28.0	52	2	>30			Water dump
1700	79:38.0	54	16	2			
1701	79:40.5	54	8	1			
1736	81:08.0	55	20	3			
1737	81:10.5	55	10	1			
1771	82:38.0	56	22	1			

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
1772	82:40.5	56	14	2			
1843	85:38.0	58	24	2			
1844	85:40.5	58	16	1			
1916	88:40.5	60	—	>30			Water dump
1934	89:25.5	60	20	1			
1935	89:28.0	60	20	2			
1936	89:30.5	60	28	8			
1952	90:10.5	61	10	6			
1970	90:55.5	61	16	1			
1972	91:00.5	61	22	5			
1973	91:03.0	61	30	3			
1988	91:40.5	62	14	2			
2006	92:25.5	62	12	3			
2008	92:30.5	62	16	3			
2009	92:33.0	62	26	3			
2024	93:10.5	63	16	4			
2043	93:58.0	63	10	1			
2044	94:00.5	63	12	2			
2045	94:03.0	63	20	1			
2060	94:40.5	64	24	>30			
2061	94:43.0	64	—	>30			
2080	95:30.5	64	12	2			
2081	95:33.0	64	12	1			
2097	96:13.0	65	—	5			
2116	97:00.5	65	14	1			
2117	97:03.0	65	18	1			
2133	97:43.0	66	4	1			
2150	98:25.5	66	2	1			
2151	98:28.0	66	8	3			
2153	98:33.0	66	—	1			
2169	99:13.0	67	8	>30			
2184	99:50.5	67	—	>30			Water dump
2185	99:53.0	67	—	>30			Water dump
2186	99:55.5	67	—	>30			Water dump
2187	99:58.0	67	—	>30			Water dump
2188	100:00.5	67	—	>30			Water dump
2189	100:03.0	67	2	>30			Water dump
2190	100:05.5	67	2	>30			Water dump
2205	100:43.0	68	2	>30			Water dump
2223	101:28.0	68	14	1			
2224	101:30.5	68	16	2			
2225	101:33.0	68	8	1			
2226	101:35.5	68	20	1			
2261	103:03.0	69	22	1			
2262	103:05.5	69	24	4			
2278	103:45.5	70	4	4			
2290	104:15.5	70	22	1			
2314	105:15.5	71	12	16			
2330	105:55.5	71	2	1			
2333	106:03.0	71	14	1			

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
2335	106:08.0	71	16	1			
2350	106:45.5	72	18	13			
2365	107:23.0	72	2	1			
2368	107:30.5	72	12	1			
2371	107:38.0	72	16	1			
2386	108:15.5	73	34	5			
2407	109:08.0	73	24	2			
2423	109:48.0	74	2	3			
2470	111:45.5	75	—	>30			Water dump
2471	111:48.0	75	—	>30			Water dump
2472	111:50.5	75	—	>30			Water dump
2473	111:53.0	75	--	>30			Water dump
2474	111:55.5	75	—	>30			Water dump
2475	111:58.0	75	2	>30			Water dump
2476	112:00.5	75	2	>30			Water dump decay
2477	112:03.0	75	14	>30			Water dump decay
2478	112:05.5	75	10	26			Water dump decay
2479	112:08.0	75	18	21			Water dump decay
2480	112:10.5	75	26	15			Water dump decay
2495	112:48.0	76	20	15			
2506	113:15.5	76	—	>30			Water dump
2507	113:18.0	76	--	>30			Water dump
2508	113:20.5	76	—	>30			Water dump
2509	113:23.0	76	—	>30			Water dump
2510	113:25.5	76	—	>30			Water dump
2511	113:28.0	76	—	>30			Water dump
2512	113:30.5	76	—	>30			Water dump decay
2513	113:33.0	76	10	>30			Water dump decay
2514	113:35.5	76	12	>30			Water dump decay
2515	113:38.0	76	12	>30			Water dump decay
2516	113:40.5	76	20	>30			Water dump decay
2531	114:18.0	77	28	16			
2532	114:20.5	77	—	>30			
2548	115:00.5	77	—	20			
2549	115:03.0	77	4	7			
2550	115:05.5	77	12	1			
2552	115:10.5	77	2	4			
2568	115:50.5	78	4	7			
2588	116:40.5	78	10	1			
2604	117:20.5	79	10	22			
2622	118:05.5	79	6	1			
2658	119:35.5	80	10	>30			
2659	119:38.0	80	10	4			
2660	119:40.5	80	12	3			
2661	119:43.0	80	18	1			
2692	121:00.5	81	—	1			
2695	121:08.0	81	4	5			
2696	121:10.5	81	6	10			
2697	121:13.0	81	16	5			
2732	122:38.0	82	—	2			

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
2733	122:40.5	82	2	4			
2734	122:43.0	82	2	1			
2735	122:45.5	82	14	1			
2736	122:48.0	82	18	2			
2737	122:50.5	82	24	1			
2750	123:23.0	83	2	>30			Water dump
2762	123:53.0	83	—	>30			Water dump
2763	123:55.5	83	—	>30			Water dump
2764	123:58.0	83	—	>30			Water dump
2765	124:00.5	83	—	>30			Water dump decay
2766	124:03.0	83	—	>30			Water dump decay
2767	124:05.5	83	2	15			Water dump decay
2768	124:08.0	83	6	15			Water dump decay
2769	124:10.5	83	14	25			Water dump decay
2770	124:13.0	83	20	20			Water dump decay
2771	124:15.5	83	18	20			Water dump decay
2786	124:53.0	84	10	11			
2806	125:43.0	84	14	1			
2840	127:08.0	85	6	1			
2841	127:10.5	85	16	3			
2842	127:13.0	85	24	4			
2843	127:15.5	85	12	3			
2877	128:40.5	86	14	1			
2878	128:43.0	86	16	1			
2879	128:45.5	86	18	1			
2880	128:48.0	86	20	2			
2895	129:25.5	87	16	15			
2900	129:38.0	87	12	1			
2930	130:55.5	88	20	5			
2951	131:48.0	88	20	2			
2967	132:28.0	88	—	2			
2987	133:18.0	89	14	2			
3003	133:58.0	90	10	2			
3022	134:45.5	90	14	2			
3023	134:48.0	90	14	2			
3024	134:50.5	90	10	3			
3039	135:28.0	91	—	>30			Water dump
3051	135:58.0	91	—	>30			Water dump
3052	136:00.5	91	—	>30			Water dump
3053	136:03.0	91	—	>30			Water dump
3054	136:05.5	91	—	>30			Water dump
3055	136:08.0	91	—	>30			Water dump
3056	136:10.5	91	—	>30			Water dump
3057	136:13.0	91	—	>30			Water dump
3058	136:15.5	91	4	>30			Water dump decay
3060	136:18.0	91	8	20			Water dump decay
3077	137:00.5	92	—	20			
3095	137:45.5	92	8	1			
3096	137:48.0	92	14	1			
3097	137:50.5	92	14	4			

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
3113	138:30.5	93	6	13			
3133	139:20.5	93	14	1			
3134	139:23.0	93	16	2			
3169	140:50.5	94	12	1			
3170	140:53.0	94	16	4			
3185	141:30.5	95	18	10			
3206	142:23.0	95	16	2			
3222	143:03.0	96	—	1			
3241	143:50.5	96	16	1			
3242	143:53.0	96	6	1			
3273	145:10.5	97	—	>30			Water dump
3274	145:13.0	97	—	>30			Water dump
3275	145:15.5	97	2	>30			Water dump
3276	145:18.0	97	2	>30			Water dump
3277	145:20.5	97	2	>30			Water dump
3278	145:23.0	97	2	>30			Water dump
3279	145:25.5	97	2	>30			Water dump
3294	146:03.0	98	—	>30			Water dump
3312	146:48.0	98	8	1			
3314	146:53.0	98	14	2			
3315	146:55.5	98	20	1			
3330	147:33.0	99	32	3			

STS-9

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
14	1:52.0	2	2	>30	—	>30	
29	2:29.5	2	—	12	—	7	Bright image
40	2:57.0	3	—	14	—	15	Bright image
41	2:59.5	3	—	9	—	16	Bright image
42	3:02.0	3	—	8	—	18	Bright image
43	3:04.5	3	—	13	—	23	Bright image
44	3:07.0	3	—	>30	—	20	
64	3:57.0	3	—	2	—	2	
86	4:52.0	4	—	>30	—	>30	
100	5:27.0	4	—	>30	—	25	Bright image
101	5:29.5	4	—	26	—	26	Bright image
102	5:32.0	4	—	11	—	13	Bright image
103	5:34.5	4	—	10	—	6	Bright image
122	6:22.0	5	—	8	—	5	
136	6:57.0	5	—	12	—	12	
137	6:59.5	5	—	15	—	15	
138	7:02.0	5	—	10	—	10	
153	7:39.5	6			—	5	
172	8:27.0	6	—	11	—	11	
208	9:57.0	7	—	5	—	4	

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
212	10:07.0	7	—	3	—	2	
286	13:02.0	9			—	7	
287	13:04.5	9			—	3	
288	13:07.0	9	—	7	—	20	
291	13:14.5	9	—	>30	—	>30	
295	13:24.5	10	—	1	—	2	
302	13:42.0	10			—	1	
304	13:47.0	10	2	1	—	1	
319	14:24.5	10	—	12	—	7	
320	14:27.0	10	—	20	—	>30	
321	14:29.5	10	—	8	—	>30	
322	14:32.0	10	—	5	—	15	
323	14:34.5	10			—	1	
340	15:17.0	11	—	1	—	3	
376	16:47.0	11	—	1	—	4	
391	17:24.5	12			—	2	
462	20:22.0	14	10	>30	14	>30	
463	20:24.5	14	4	>30	6	>30	
464	20:27.0	14	—	>30	2	>30	
465	20:29.5	14	—	5	—	5	
466	20:32.0	14	—	2	—	2	
483	21:14.5	15			—	5	
484	21:17.0	15	—	15	—	16	
498	21:52.0	15	4	>30	2	>30	
499	21:54.5	15	2	>30	—	>30	
500	21:57.0	15	—	4	—	4	
534	23:22.0	16	—	21	4	>30	
535	23:24.5	16	—	>30	—	>30	
536	23:27.0	16	—	3	—	3	
537	23:29.5	16			—	2	
555	24:14.5	17	—	1			
569	24:49.5	17	6	2	4	3	
570	24:52.0	17	—	22	4	>30	
571	24:54.5	17	—	1	2	>30	
572	24:57.0	17	—	1	—	1	
580	25:17.0	17	—	7	—	6	
591	25:44.5	18	—	1	2	9	
607	26:24.5	18	—	1	—	1	
608	26:27.0	18	—	1			
609	26:29.5	18	—	1			
611	26:34.5	18	—	1	—	1	
612	26:37.0	18	—	2	—	1	
627	27:14.5	19	—	>30	—	>30	
641	27:49.5	19	—	>30	—	>30	
662	28:42.0	20	—	15			
663	28:44.5	20	—	21	—	12	
677	29:19.5	20	—	>30	2	>30	
698	30:12.0	21	—	13			
713	30:49.5	21	—	>30	—	>30	
734	31:42.0	22	—	>30	—	25	

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
748	32:17.0	22	—	6	4	7	
749	32:19.5	22	—	6	—	7	
770	33:12.0	23	—	>30	—	25	
784	33:47.0	23	—	>30	—	>30	
806	34:42.0	24	—	16	—	15	
821	35:17.0	24	12	15	6	15	
822	35:19.5	24	6	8	4	8	
824	35:24.5	24			2	1	
826	35:29.5	24			—	1	
829	35:37.0	24			4	1	
830	35:39.5	24			4	1	
836	35:54.5	25			2	1	
841	36:07.0	25	6	1	10	1	
857	36:47.0	25	12	1	22	4	
858	36:49.5	25	6	2	8	2	
860	36:54.5	25			2	1	
861	36:57.0	25			2	1	
862	36:59.5	25			2	1	
894	38:19.5	26	6	3	8	10	
895	38:22.0	26	2	2	4	2	
896	38:24.5	26			2	3	
897	38:27.0	26	—	1	2	1	
899	38:32.0	26			4	10	
900	38:34.5	26	—	17	2	>30	Water dump
901	38:37.0	26	—	5	2	>30	Water dump
902	38:39.5	26	—	11	2	>30	Water dump
903	38:42.0	26	—	8	2	>30	Water dump
904	38:44.5	27	—	10	2	>30	Water dump
905	38:47.0	27	—	8	2	>30	Water dump
906	38:49.5	27	—	14	4	>30	Water dump
907	38:52.0	27	—	20	2	>30	Water dump
908	38:54.5	27	—	25	2	>30	Water dump
909	38:57.0	27	—	18	2	>30	Water dump
910	38:59.5	27	—	15	2	>30	Water dump
911	39:02.0	27	—	>30	2	>30	Water dump
912	39:04.5	27	—	3	16	10	Water dump decay
928	39:44.5	27	22	1	24	1	
936	40:04.5	27			2	2	
964	41:14.5	28	20	1	20	1	
965	41:17.0	28	10	1	10	2	
979	41:52.0	29			2	1	
983	42:02.0	29			8	1	
984	42:04.5	29			8	1	
1000	42:44.5	29			16	2	
1001	42:47.0	29	8	1	6	1	
1002	42:49.5	29	4	5	4	4	
1021	43:37.0	30			14	3	
1036	44:14.5	30	4	1	4	2	
1037	44:17.0	30	2	>30	2	>30	Water dump
1038	44:19.5	30	2	>30	2	>30	Water dump

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
1039	44:22.0	30	—	>30	2	>30	Water dump
1040	44:24.5	30	—	20	4	>30	Water dump
1041	44:27.0	30	—	12	2	>30	Water dump
1042	44:29.5	30	—	12	4	>30	Water dump
1043	44:32.0	30	—	15	4	>30	Water dump
1044	44:34.5	30	—	12	4	>30	Water dump
1045	44:37.0	30	—	12	2	>30	Water dump
1046	44:39.5	31	—	15	2	>30	Water dump
1047	44:42.0	31	—	6	2	>30	Water dump
1048	44:44.5	31	—	12	4	>30	Water dump
1049	44:47.0	31	—	10	2	>30	Water dump
1050	44:49.5	31	—	>30	2	>30	Water dump
1051	44:52.0	31	—	15	4	>30	Water dump
1052	44:54.5	31	—	14	4	>30	Water dump
1053	44:57.0	31	—	15	4	>30	Water dump
1054	44:59.5	31	—	20	2	>30	Water dump
1055	45:02.0	31	—	>30	—	>30	Water dump
1056	45:04.5	31	2	>30	2	>30	Water dump
1057	45:07.0	31	2	>30	4	>30	Water dump
1058	45:09.5	31	2	>30	2	>30	Water dump
1075	45:52.0	31	—	2			
1109	47:17.0	32	2	1	2	1	
1111	47:22.0	32			2	2	
1124	47:54.5	33	—	1			
1129	48:07.0	33			10	1	
1143	48:42.0	33	8	1	8	1	
1145	48:47.0	33	2	1	—	1	
1154	49:09.5	34	—	1	2	2	
1155	49:12.0	34	—	1	4	1	
1165	49:37.0	34	8	1			
1179	50:12.0	34			6	1	
1184	50:24.5	34			—	1	
1217	51:47.0	35			4	1	
1220	51:54.5	35			—	1	
1250	53:09.5	36			18	1	
1251	53:12.0	36			6	1	
1321	56:09.5	38			12	1	
1357	57:39.5	39	10	2	12	1	
1378	58:29.5	40	6	1	8	1	
1392	59:07.0	40	2	>30	6	>30	Water dump
1393	59:09.5	40	2	>30	2	>30	Water dump
1394	59:12.0	40	2	>30	—	>30	Water dump
1395	59:14.5	40	—	21	2	>30	Water dump
1396	59:17.0	40	—	12	—	12	Water dump
1397	59:19.5	40	—	15	—	15	Water dump
1398	59:22.0	40	—	10	—	10	Water dump
1399	59:24.5	40	—	2	—	6	Water dump
1413	60:02.0	41			—	3	
1414	60:04.5	41			8	3	
1427	60:37.0	41	18	1	14	1	

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
1430	60:44.5	41			2	4	
1431	60:47.0	41	—	2	—	5	
1432	60:49.5	41	—	3	—	3	
1433	60:52.0	41	—	3	—	3	
1434	60:54.5	41	—	2	—	3	
1435	60:57.0	41	—	8	—	7	
1436	60:59.5	41	—	2	—	1	
1437	61:02.0	41			—	1	
1438	61:04.5	41	—	1			
1440	61:09.5	42	—	1	—	1	
1441	61:12.0	42	—	2	—	3	
1444	61:19.5	42	—	5	—	7	
1445	61:22.0	42			—	1	
1446	61:24.5	42	—	3	2	7	
1447	61:27.0	42	—	1	2	7	
1448	61:29.5	42	—	2	2	12	
1449	61:32.0	42	—	4	2	9	
1464	62:09.5	42			4	2	
1467	62:17.0	42			2	2	
1468	62:19.5	42			2	1	
1469	62:22.0	42	—	1	2	2	
1471	62:27.0	42	—	1			
1479	62:47.0	43	—	1	—	5	
1480	62:49.5	43			—	1	
1481	62:52.0	43			—	1	
1482	62:54.5	43	—	1	—	3	
1483	62:57.0	43	—	3	—	2	
1484	62:59.5	43	—	4	—	1	
1485	63:02.0	43			—	1	
1498	63:34.5	43			8	4	
1499	63:37.0	43			4	3	
1500	63:39.5	43	—	3	2	6	
1501	63:42.0	43	—	2	2	3	
1502	63:44.5	43	—	3	2	2	
1503	63:47.0	43	—	2	2	3	
1504	63:49.5	43	—	2	—	2	
1505	63:52.0	43	—	8	—	4	
1506	63:54.5	43	—	3			
1512	64:09.5	44			—	1	
1513	64:12.0	44			—	1	
1514	64:14.5	44	—	8	—	25	
1515	64:17.0	44	—	2	—	5	
1516	64:19.5	44			—	2	
1517	64:22.0	44			—	1	
1520	64:29.5	44			—	1	
1534	65:04.5	44	—	3	—	5	
1535	65:07.0	44	—	1	—	1	
1536	65:09.5	44	—	1	—	1	
1557	66:02.0	45	—	1			
1570	66:34.5	45	—	2	4	20	

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
1590	67:24.5	46	2	5	—	5	
1591	67:27.0	46	8	20	4	20	
1592	67:29.5	46	12	>30	8	>30	
1606	68:04.5	46	2	>30	2	>30	Water dump
1607	68:07.0	46	—	>30	2	>30	Water dump
1628	68:59.5	47	—	>30	—	3	
1640	69:32.0	47	—	8	—	>30	
1641	69:34.5	47	—	>30	—	>30	
1662	70:27.0	48	—	1	—	1	
1663	70:29.5	48	—	3	2	20	
1676	71:02.0	48	—	16	2	>30	
1677	71:04.5	48	—	14	2	>30	
1678	71:07.0	48	—	13	2	>30	
1679	71:09.5	48	—	8	2	22	
1680	71:12.0	48			—	1	
1681	71:14.5	48	—	1	—	1	
1682	71:17.0	48	—	>30	—	>30	
1683	71:19.5	48	—	11	—	5	
1684	71:22.0	48	—	10	—	6	
1685	71:24.5	48	—	6	—	4	
1686	71:27.0	48	—	1			
1697	71:54.5	49			2	10	
1698	71:57.0	49	4	>30	6	>30	
1699	71:59.5	49	8	>30	6	>30	
1712	72:32.0	49			2	>30	Water dump
1713	72:34.5	49	—	>30	—	>30	Water dump
1728	73:12.0	50			—	1	
1730	73:17.0	50	—	1	—	1	
1731	73:19.5	50	—	1	—	1	
1733	73:24.5	50	—	2	—	7	
1734	73:27.0	50	—	3	—	3	
1735	73:29.5	50	—	6	—	6	
1748	74:02.0	50	—	4	—	>30	
1769	74:54.5	51			2	3	
1770	74:57.0	51	—	1	2	1	
1804	76:22.0	52			2	1	
1805	76:24.5	52	—	5	6	10	
1818	76:59.5	52	—	13	—	11	
1819	77:02.0	52	26	26	28	27	
1820	77:04.5	52	10	4	10	7	
1821	77:07.0	52			4	>30	
1822	77:09.5	52	—	10	2	13	
1823	77:12.0	52	—	7	—	11	
1841	77:57.0	53			14	1	
1854	78:29.5	53	8	>30	6	>30	
1855	78:32.0	53	6	>30	4	>30	
1856	78:34.5	53	2	>30	2	>30	
1857	78:37.0	53	—	>30	2	>30	
1858	78:39.5	53	—	28	2	>30	
1859	78:42.0	53	—	>30	—	>30	

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
1860	78:44.5	53	—	>30	—	>30	
1861	78:47.0	53	—	>30	—	>30	
1862	78:49.5	53	—	>30	2	>30	
1863	78:52.0	53	—	>30	—	>30	
1864	78:54.5	53	—	>30	2	>30	
1865	78:57.0	54	—	>30	2	>30	
1866	78:59.5	54	—	>30	2	>30	
1867	79:02.0	54	—	>30	2	>30	
1868	79:04.5	54	—	>30	2	>30	
1869	79:07.0	54	—	>30	2	>30	
1870	79:09.5	54	—	>30	2	>30	
1871	79:12.0	54	—	7	2	12	
1872	79:14.5	54	—	21	2	>30	
1873	79:17.0	54	—	23	2	>30	
1874	79:19.5	54	—	11	2	>30	
1875	79:22.0	54	—	3	—	5	
1876	79:24.5	54	—	19	—	>30	
1877	79:27.0	54	—	>30	—	>30	
1890	79:59.5	55	—	1	—	1	
1912	80:54.5	55	—	1	—	1	
1913	80:57.0	55	—	1	2	6	
1947	82:22.0	56			4	1	
1948	82:24.5	56	2	1	10	1	
1961	82:57.0	56	—	2	4	10	
1962	82:59.5	56	—	2	8	8	
1963	83:02.0	56	—	1	4	20	
1964	83:04.5	56	—	2	2	6	
1965	83:07.0	56	—	1	2	20	
1966	83:09.5	56	—	8	—	16	
1984	83:54.5	57	—	10	—	2	
1997	84:27.0	57	—	1	—	2	
2019	85:24.5	58	—	6	—	3	
2032	85:57.0	58			2	15	
2055	86:54.5	59	—	8	—	5	
2067	87:24.5	59	—	3	—	4	
2068	87:27.0	59	—	4	2	5	
2091	88:24.5	60	—	6	—	3	
2126	89:52.0	61	—	7			
2127	89:54.5	61			4	1	
2139	90:24.5	61	—	6	2	15	
2140	90:27.0	61			—	1	Water dump
2162	91:22.0	62	—	1	—	1	
2175	91:54.5	62	—	1	2	2	
2197	92:49.5	63	—	3			
2198	92:52.0	63	—	1	—	1	
2210	93:22.0	63			4	17	
2211	93:24.5	63	—	6	—	6	
2233	94:19.5	64	—	5			
2234	94:22.0	64	—	6	—	4	
2269	95:49.5	65	—	2	—	6	

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
2270	95:52.0	65			—	2	
2271	95:54.5	65	10	1	14	2	
2341	98:49.5	67	—	5	—	4	
2357	99:29.5	67	—	>30	—	>30	Water dump
2358	99:32.0	67	—	>30	—	>30	Water dump
2359	99:34.5	67	—	>30	—	>30	Water dump
2360	99:37.0	67	—	>30	—	>30	Water dump
2361	99:39.5	67	—	>30	—	>30	Water dump
2362	99:42.0	67	—	>30	—	>30	Water dump
2363	99:44.5	67	—	>30	—	>30	Water dump
2364	99:47.0	68	—	>30	—	>30	Water dump
2365	99:49.5	68	—	>30	—	>30	Water dump
2377	100:19.5	68	—	2	2	4	
2401	101:19.5	69			—	2	
2406	101:32.0	69			—	4	
2407	101:34.5	69			—	6	
2408	101:37.0	69	—	4	2	12	
2409	101:39.5	69	—	1	2	6	
2410	101:42.0	69			2	12	
2411	101:44.5	69	—	2	—	4	
2412	101:47.0	69	—	4	—	12	
2413	101:49.5	69	—	3	2	15	
2424	102:17.0	69			50	1	
2425	102:19.5	69	—	5	2	10	
2426	102:22.0	69	—	4	2	11	
2427	102:24.5	69			2	15	
2428	102:27.0	69	—	6	—	16	
2429	102:29.5	69	—	6	2	17	
2430	102:32.0	69	—	6	2	20	
2447	103:14.5	70	—	6	2	11	
2448	103:17.0	70	—	5	4	12	
2449	103:19.5	70	2	1	28	7	
2460	103:47.0	70	6	1	8	1	
2461	103:49.5	70	4	18	6	21	
2496	105:17.0	71			20	3	
2497	105:19.5	71			18	13	
2498	105:22.0	71	2	4	10	12	
2499	105:24.5	71	2	2	6	2	
2500	105:27.0	71	—	3	2	5	
2501	105:29.5	71	—	2	2	10	
2512	105:57.0	72	—	1	2	1	
2517	106:09.5	72			—	1	
2518	106:12.0	72			—	1	
2519	106:14.5	72			10	1	
2520	106:17.0	72	20	1	28	1	
2532	106:47.0	72	16	12	22	14	
2533	106:49.5	72	6	12	6	14	
2534	106:52.0	72	—	3	—	4	
2535	106:54.5	72	—	8	—	5	
2536	106:57.0	72	—	3	—	3	

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
2537	106:59.5	72	—	5	—	1	
2538	107:02.0	72	—	2	—	2	
2540	107:07.0	72	—	2	—	2	
2541	107:09.5	72	—	5	—	4	
2556	107:47.0	73	—	>30	—	>30	Water dump decay
2569	108:19.5	73			—	1	
2592	109:14.5	74	—	1			
2604	109:44.5	74	—	1	2	1	
2605	109:47.0	74	—	2	2	4	
2606	109:49.5	74			—	1	
2640	111:14.5	75			4	4	
2641	111:17.0	75	—	2	2	2	
2664	112:14.5	76	—	8	—	5	
2712	114:14.5	77			—	2	
2713	114:17.0	77	—	1	—	1	
2735	115:12.0	78	—	>30	—	15	Water dump
2736	115:14.5	78	—	>30	—	>30	Water dump
2747	115:42.0	78	—	1	—	1	
2748	115:44.5	78	—	1	—	4	
2773	116:47.0	79			22	1	
2783	117:12.0	79			2	3	
2784	117:14.5	79	—	1	2	1	
2808	118:14.5	80	—	1	—	2	
2819	118:42.0	80	—	5	2	7	
2820	118:44.5	80	—	1	—	1	
2843	119:42.0	81	—	6	—	9	
2844	119:44.5	81	—	4	—	4	
2854	120:09.5	81	2	3	4	4	
2855	120:12.0	81	—	7	—	7	
2856	120:14.5	81	6	4	8	4	
2863	120:34.5	81	—	1	—	2	
2889	121:39.5	82	2	>30	2	>30	Water dump
2890	121:42.0	82	2	>30	2	>30	Water dump
2891	121:44.5	82	2	>30	2	>30	Water dump
2892	121:47.0	82	—	>30	2	>30	Water dump
2893	121:49.5	82	—	1	—	>30	Water dump
2911	122:34.5	83	2	1	14	1	
2925	123:09.5	83	24	18	24	18	
2926	123:12.0	83	6	5	6	6	
2933	123:29.5	83	—	2	—	2	
2940	123:47.0	84			—	1	
2944	123:57.0	84	—	1	2	2	
2945	123:59.5	84			2	3	
2946	124:02.0	84			26	2	
2947	124:04.5	84			22	1	
2948	124:07.0	84	10	1	20	1	
2949	124:09.5	84	14	>30	20	>30	
2960	124:37.0	84	22	1	24	1	
2961	124:39.5	84	12	2	12	2	
2962	124:42.0	84	6	>30	8	>30	

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
2963	124:44.5	84	—	13	2	18	
2978	125:22.0	85	—	2	—	1	
2979	125:24.5	85	—	2	—	3	
2985	125:39.5	85	—	1	—	1	
2996	126:07.0	85			4	1	
2997	126:09.5	85	—	2	4	1	
2999	126:14.5	85			2	1	
3000	126:17.0	85			4	10	
3001	126:19.5	85			2	1	
3032	127:37.0	86	—	1			
3033	127:39.5	86	—	>30	—	>30	
3034	127:42.0	86	—	>30	—	>30	Water dump
3035	127:44.5	86	—	>30	—	>30	Water dump
3036	127:47.0	86	—	>30	—	>30	Water dump
3066	129:02.0	87	24	1	60	1	
3068	129:07.0	87	—	3	—	17	
3069	129:09.5	87	—	8	—	16	
3070	129:19.5	87	—	1	—	2	
3071	129:14.5	87	—	1	4	2	
3072	129:17.0	87			—	1	
3092	130:07.0	88	—	3	2	1	
3093	130:09.5	88	—	1	2	1	
3112	130:57.0	88	—	1			
3113	130:59.5	88	—	1	2	10	
3114	131:02.0	89	—	1	2	3	
3115	131:04.5	89	—	2	2	9	
3116	131:07.0	89	—	3	2	8	
3117	131:09.5	89			2	1	
3118	131:12.0	89	—	3	—	6	
3130	131:42.0	89	14	1	24	1	
3144	132:17.0	89	—	1	—	1	
3174	133:32.0	90	28	1	30	1	
3175	133:34.5	90	20	8	30	8	
3176	133:37.0	90	20	12	28	11	
3177	133:39.5	90	16	12	22	12	
3178	133:42.0	90	8	7	14	6	
3179	133:44.5	90	—	8	10	20	
3180	133:47.0	90			2	4	
3181	133:49.5	90	—	4	—	15	
3182	133:52.0	90	—	1	2	10	
3183	133:54.5	90			—	6	
3184	133:57.0	90			—	3	
3209	134:59.5	91	26	1	48	1	
3213	135:09.5	91	2	3	36	5	
3214	135:12.0	91	2	4	24	14	
3215	135:14.5	91	2	11	18	19	
3216	135:17.0	91	2	3	14	13	
3217	135:19.5	91	—	3	8	22	
3218	135:22.0	91	—	4	4	18	
3219	135:24.5	91	—	3	2	5	

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
3236	136:07.0	92	2	1	8	1	
3246	136:32.0	92	—	1	2	1	
3247	136:34.5	92			2	1	
3248	136:37.0	92			—	1	
3282	138:02.0	93	26	7	34	4	
3283	138:04.5	93	28	7	34	7	
3284	138:07.0	93			16	8	
3313	139:19.5	94			12	1	
3318	139:32.0	94			2	5	
3319	139:34.5	94			2	3	
3320	139:37.0	94	—	1	2	3	
3321	139:39.5	94	—	1	4	2	
3322	139:42.0	94			2	5	
3323	139:44.5	94			2	3	
3324	139:47.0	94	—	1	2	8	
3325	139:49.5	94	—	1	2	1	
3326	139:52.0	94	—	3	2	14	
3327	139:54.5	94	—	2	2	8	
3328	139:57.0	94	—	2	2	4	
3389	142:29.5	96			2	5	
3390	142:32.0	96			2	4	
3399	142:54.5	96	—	1	—	2	
3400	142:57.0	97			—	1	
3401	142:59.5	97	—	1	—	4	
3403	143:04.5	97	—	1	—	1	
3404	143:07.0	97	—	1	—	1	
3415	143:34.5	97	—	1	—	1	
3418	143:42.0	97	14	1	10	1	
3425	143:59.5	97			—	1	
3451	145:04.5	98			2	1	
3461	145:29.5	98	—	3	—	2	
3462	145:32.0	98			—	2	
3463	145:34.5	98	—	1	—	1	
3464	145:37.0	98	—	1	—	2	
3479	146:14.5	99			2	1	
3483	146:24.5	99	—	1	10	2	
3484	146:27.0	99	4	2	4	3	
3495	146:54.5	99			66	6	
3496	146:57.0	99	2	4	18	12	
3497	146:59.5	99	—	1	14	8	
3498	147:02.0	99			10	6	
3499	147:04.5	99			6	10	
3500	147:07.0	99			6	4	
3501	147:09.5	99	—	1	2	10	
3502	147:12.0	99	—	2	2	6	
3503	147:14.5	99	—	1	2	4	
3510	147:32.0	100	—	1			
3513	147:39.5	100	—	1			
3516	147:47.0	100	—	1	—	1	
3517	147:49.5	100			—	1	

FRAME NO.	MISSION ELAPSED TIME	ORBIT NO.	CAMERA 1 EXP	CAMERA 1 NUMBER OF PARTICLES	CAMERA 2 EXP	CAMERA 2 NUMBER OF PARTICLES	COMMENTS
3519	147:54.5	100			—	1	
3521	147:59.5	100	—	2			
3522	148:02.0	100			—	1	
3523	148:04.5	100			—	1	
3524	148:07.0	100			—	4	
3532	148:27.0	100	—	1	—	1	
3533	148:29.5	100	—	1	—	1	
3547	149:04.5	101	—	5	—	2	
3548	149:07.0	101			2	1	
3549	149:09.5	101			2	2	
3550	149:12.0	101			4	1	
3552	149:17.0	101			8	1	
3553	149:19.5	101			12	3	
3557	149:29.5	101			16	1	
3558	149:32.0	101			18	5	
3567	149:54.5	101	—	>30			
3568	149:57.0	101	—	>30			
3569	149:59.5	101	—	>30			
3570	150:02.0	101	—	>30			
3582	150:32.0	102	—	2			
3586	150:42.0	102	—	12			
3592	150:57.0	102	—	1			
3597	151:09.5	102	18	1			

APPENDIX B. ANALYZED PARTICLE DATA

PARTICLE	BACKGROUND Cam 1	Cam 2	-- EXPOSURE -- Cam 1	Cam 2	Sun Coel	- DISTANCE - Endpt1	Endpt2	--- VELOCITY --- Radial	Trnvse	Total	Size
2- 255- 1	37.0	36.0	.80	.80	123.5	12.82	14.11	1.62	.84	1.83	33.34
2- 255- 2	37.0	37.0	1.00	1.00	123.5	19.86	22.06	2.20	.77	2.33	35.45
2- 255- 3	36.0	37.0	.44	.52	123.5	6.99	7.15	.35	.55	.65	73.27
2- 255- 6	37.0	38.0	.80	.80	123.5	29.24	29.86	.77	.24	.81	65.01
2- 256- 1	36.0	37.0	.80	.80	123.5	27.36	27.90	.68	.48	.83	71.53
2- 256- 2	36.0	37.0	.80	.80	123.5	3.97	4.71	.92	1.54	1.80	73.12
2- 256- 4	0.0	0.0	.20	.20	123.5	4.46	4.48	.06	1.07	1.07	N/A
2- 258- 1	38.0	38.0	.80	.80	123.8	7.14	7.60	.58	.64	.86	80.21
2- 258- 2	38.0	38.0	.80	.80	123.8	26.27	27.24	1.21	.71	1.40	178.90
2- 258- 3	38.0	38.0	.80	.80	123.8	19.76	21.59	2.29	.81	2.43	54.89
2- 258- 4	38.0	38.0	.80	.80	123.8	18.60	19.66	1.33	2.50	2.83	55.00
2- 258- 5	0.0	0.0	.80	.80	123.8	10.77	12.28	1.89	1.29	2.29	N/A
2- 258- 6	38.0	38.0	.20	.20	123.8	18.60	18.82	1.08	5.52	5.63	25.04
2- 258- 7	38.0	38.0	.80	.80	123.8	12.49	13.03	.67	.93	1.15	76.18
2- 258- 9	0.0	0.0	.80	.80	123.8	13.34	14.38	1.31	2.62	2.92	N/A
2- 258-14	37.0	38.0	.39	.08	123.8	7.95	8.01	.73	1.70	1.85	22.33
9- 462- 1	77.0	71.0	1.80	1.80	131.1	10.93	11.50	.32	.10	.34	29.36
9- 462- 2	77.0	72.0	6.80	6.80	131.1	25.90	34.53	1.27	.20	1.28	44.38
9- 462- 3	78.0	71.0	10.00	14.10	131.1	15.68	19.82	.41	.05	.42	31.27
9- 462- 4	76.0	74.0	6.80	6.80	131.1	14.99	20.20	.77	.12	.77	24.49
9- 462- 5	77.0	71.0	10.00	14.10	131.1	35.60	39.31	.37	.14	.40	31.18
9- 462- 7	77.0	72.0	10.00	14.10	131.1	32.09	45.09	1.30	.13	1.31	60.90
9- 462- 8	77.0	70.0	10.00	14.10	131.1	34.70	45.96	1.13	.13	1.13	37.72
9- 462-10	76.0	72.0	2.80	2.80	131.1	6.81	7.84	.37	.11	.38	N/A
9- 462-15	80.0	71.0	10.00	14.10	131.1	21.00	26.70	.57	.09	.58	33.58
9- 462-17	78.0	71.0	10.00	14.10	131.1	17.65	22.37	.47	.03	.47	31.11
9- 462-18	77.0	72.0	10.00	14.10	131.1	15.96	17.60	.16	.01	.16	16.13
9- 462-20	76.0	72.0	10.00	14.10	131.1	19.53	23.61	.41	.02	.41	25.81
9- 821- 1	88.0	70.0	6.80	6.80	128.0	34.49	43.21	1.28	.55	1.40	195.99
9- 821- 2	93.0	69.0	5.80	5.80	128.0	41.01	44.90	.67	.75	1.01	108.84
9- 821- 3	88.0	69.0	.80	.80	128.0	21.35	21.72	.46	1.27	1.35	61.54
9- 821- 5	93.0	70.0	2.80	2.80	128.0	30.35	32.45	.75	1.03	1.27	75.71
9- 821- 6	90.0	68.0	1.80	1.80	128.0	35.79	38.78	1.66	.82	1.85	118.79
9- 821- 7	92.0	69.0	5.80	5.80	128.0	40.92	49.31	1.45	1.32	1.96	93.69
9- 821- 8	88.0	71.0	2.80	2.80	128.0	38.18	45.61	2.65	1.05	2.85	174.40
9- 821- 9	89.0	71.0	2.00	2.00	128.0	30.48	31.70	.61	1.23	1.37	59.67
9- 821-10	88.0	72.0	.80	.80	128.0	16.47	16.61	.17	.95	.96	127.53
9- 821-11	91.0	70.0	3.80	3.80	128.0	49.50	60.14	2.80	.80	2.91	103.62
9- 821-12	91.0	70.0	1.80	1.80	128.0	44.66	51.19	3.63	.95	3.75	83.55
9- 822- 2	91.0	69.0	.20	.20	103.8	4.93	4.95	.13	.36	.38	18.13
9-1036- 1	0.0	0.0	2.80	2.80	90.0	48.14	58.17	3.58	.41	3.61	N/A
9-1037- 1	99.0	72.0	.80	.80	90.1	9.72	10.52	1.00	1.28	1.62	60.77
9-1037- 2	99.0	72.0	1.00	1.00	90.1	14.96	16.34	1.38	2.02	2.44	92.19
9-1037- 3	99.0	74.0	1.00	1.00	90.1	16.94	17.37	.43	.45	.62	63.09
9-1037- 4	97.0	76.0	.80	.80	90.1	17.85	18.56	.88	1.35	1.61	N/A
9-1037- 5	98.0	73.0	.50	.45	90.1	7.34	7.58	.54	1.22	1.33	50.69
9-1037- 6	99.0	75.0	1.80	1.80	90.1	29.08	31.02	1.08	.66	1.26	201.82
9-1037- 7	101.0	79.0	.80	.80	90.1	19.39	19.94	.69	.85	1.09	149.55
9-1037- 8	98.0	78.0	1.80	1.80	90.1	9.60	10.32	.40	.79	.89	200.75
9-1037- 9	89.0	82.0	.80	.80	90.1	8.74	9.16	.53	.83	.99	57.65

PARTICLE	BACKGROUND Cam 1	Cam 2	-- EXPOSURE -- Cam 1	Cam 2	Sun Coel	- DISTANCE - Endpt1	Endpt2	--- VELOCITY --- Radial	Trnvse	Total	Size
9-1038- 1	92.0	70.0	.80	.80	90.2	10.22	11.02	1.00	.55	1.14	47.69
9-1038- 2	0.0	0.0	.80	.80	90.2	13.39	14.06	.84	1.01	1.31	N/A
9-1038- 3	96.0	72.0	.80	.80	90.2	12.74	13.11	.46	.22	.51	100.17
9-1038- 4	0.0	0.0	1.00	1.00	90.2	10.16	11.15	.99	3.49	3.63	N/A
9-1038- 5	97.0	72.0	.80	.80	90.2	20.50	20.81	.39	.21	.44	106.85
9-1038- 7	98.0	73.0	1.00	1.00	90.2	43.55	44.97	1.41	.22	1.43	133.60
9-1038- 8	98.0	72.0	1.00	1.00	90.2	37.71	38.77	1.05	.34	1.11	155.74
9-1038- 9	98.0	75.0	1.00	1.00	90.2	29.08	29.70	.62	.57	.84	162.60
9-1038-10	98.0	73.0	1.00	1.00	90.2	24.49	24.93	.44	.28	.52	87.95
9-1038-11	99.0	74.0	.80	.80	90.2	27.37	28.49	1.40	.36	1.44	55.16
9-1038-13	88.0	74.0	.80	.80	90.2	10.61	11.01	.51	.25	.56	77.62
9-1038-14	90.0	75.0	1.00	1.00	90.2	28.84	30.09	1.26	.57	1.38	181.82
9-1038-15	91.0	78.0	.80	.80	90.2	38.48	39.59	1.38	.72	1.55	96.01
9-1038-16	75.0	78.0	.80	.80	90.2	11.81	12.10	.37	.23	.43	87.59
9-1038-17	96.0	71.0	.80	.80	90.2	5.18	5.28	.14	.48	.50	25.70
9-1039- 1	65.0	0.0	.80	.80	90.2	26.70	27.22	.65	.56	.86	N/A
9-1039- 3	94.0	69.0	1.00	1.00	90.2	20.56	21.82	1.26	.31	1.29	49.69
9-1039- 5	65.0	0.0	1.00	1.00	90.2	44.44	47.51	3.07	.32	3.08	N/A
9-1039- 6	97.0	72.0	.80	.80	90.2	14.34	15.45	1.38	1.16	1.80	89.81
9-1039- 7	100.0	72.0	.80	.80	90.2	25.34	25.81	.59	.40	.71	102.81
9-1039- 8	97.0	72.0	.80	.80	90.2	13.81	14.09	.35	.55	.66	50.04
9-1039- 9	93.0	70.0	.80	.80	90.2	16.74	17.16	.52	.47	.70	90.76
9-1039-10	96.0	72.0	.80	.80	90.2	10.34	10.99	.81	.24	.85	53.62
9-1039-11	98.0	72.0	.80	.80	90.2	30.35	31.02	.84	.51	.98	80.11
9-1039-14	102.0	74.0	.80	.80	90.2	34.04	34.04	.00	.37	.37	69.33
9-1039-15	65.0	0.0	.80	.80	90.2	9.54	9.82	.35	1.10	1.16	N/A
9-1039-16	95.0	74.0	.80	.80	90.2	11.79	12.09	.39	.63	.74	131.74
9-1039-19	93.0	79.0	.80	.80	90.2	3.65	4.03	.47	.27	.54	23.05
9-1039-20	93.0	76.0	.80	.80	90.2	15.24	16.14	1.12	.93	1.46	81.40
9-1039-21	90.0	85.0	.80	.80	90.2	20.82	21.13	.39	.31	.49	91.10
9-1039-22	91.0	78.0	.80	.80	90.2	37.15	39.26	2.65	.43	2.68	151.20
9-1039-23	88.0	75.0	.80	.80	90.2	35.90	36.86	1.21	.43	1.28	208.58
9-1055- 2	73.0	81.0	1.00	1.00	89.9	36.21	37.19	.98	.63	1.17	102.90
9-1055- 3	76.0	87.0	.80	.80	89.9	39.65	42.05	3.01	.42	3.04	373.47
9-1055- 4	90.0	73.0	.80	.80	89.9	25.72	26.21	.62	.49	.79	109.58
9-1055- 5	87.0	76.0	.80	.80	89.9	47.99	49.70	2.14	.77	2.28	186.85
9-1055- 6	90.0	77.0	.80	.80	89.9	21.42	22.09	.84	1.12	1.40	95.09
9-1055- 7	88.0	74.0	.80	.80	89.9	40.75	43.31	3.20	.42	3.23	99.93
9-1055- 9	0.0	0.0	1.00	1.00	89.9	16.40	17.00	.59	1.41	1.53	N/A
9-1055-10	0.0	0.0	1.00	1.00	89.9	14.38	15.99	1.61	3.22	3.60	N/A
9-1055-11	95.0	76.0	.80	.80	89.9	24.46	25.83	1.71	.43	1.76	55.21
9-1055-13	102.0	80.0	.80	.80	89.9	27.92	29.08	1.45	.78	1.65	73.90
9-1055-14	101.0	84.0	.80	.80	89.9	27.88	29.04	1.45	.53	1.54	116.16
9-1055-15	100.0	83.0	.80	.80	89.9	14.38	14.84	.58	.78	.97	270.89
9-1055-16	95.0	80.0	.80	.80	89.9	18.11	18.34	.29	.64	.71	78.87
9-1055-17	96.0	83.0	.80	.80	89.9	23.97	24.39	.52	.48	.70	126.96
9-1055-18	100.0	85.0	.80	.80	89.9	11.75	12.62	1.09	1.57	1.91	96.89
9-1055-19	0.0	85.0	.80	.80	89.9	19.77	20.05	.35	.40	.53	180.01
9-1056- 2	84.0	73.0	.80	.80	89.8	18.45	18.70	.32	.56	.64	69.37
9-1056- 4	87.0	73.0	.80	.80	89.8	8.64	9.03	.48	1.11	1.21	60.07

PARTICLE	BACKGROUND Cam 1	BACKGROUND Cam 2	-- EXPOSURE -- Cam 1	-- EXPOSURE -- Cam 2	Sun Coel	- DISTANCE - Endpt1	- DISTANCE - Endpt2	--- VELOCITY --- Radial	--- VELOCITY --- Trnvse	--- VELOCITY --- Total	Size
9-1056- 5	85.0	77.0	.80	.80	89.8	24.36	24.81	.55	.70	.89	53.01
9-1056- 6	90.0	75.0	1.00	1.00	89.8	15.00	17.20	2.19	.60	2.27	71.89
9-1056- 7	90.0	74.0	.80	.80	89.8	24.05	25.83	2.22	1.10	2.48	90.05
9-1056- 8	95.0	74.0	.80	.80	89.8	7.01	7.19	.22	.97	.99	74.33
9-1056- 9	0.0	0.0	.80	.80	89.8	16.21	16.41	.24	.94	.97	N/A
9-1056-10	91.0	77.0	.80	.80	89.8	10.04	10.42	.47	.17	.50	35.27
9-1056-11	97.0	77.0	.80	.80	89.8	13.05	13.17	.15	.98	.99	61.52
9-1056-12	93.0	81.0	1.00	1.00	89.8	20.18	20.46	.27	.75	.80	67.24
9-1056-13	91.0	80.0	.80	.80	89.8	11.69	12.34	.81	2.68	2.80	N/A
9-1056-14	92.0	82.0	.80	.80	89.8	37.57	39.73	2.69	.46	2.73	546.65
9-1056-15	92.0	79.0	.80	.80	89.8	17.72	17.93	.26	.70	.75	66.81
9-1056-16	95.0	88.0	.80	.80	89.8	12.75	13.11	.44	.13	.46	78.15
9-1056-17	101.0	94.0	.80	.80	89.8	28.70	29.30	.75	.27	.80	340.34
9-1143- 1	85.0	69.0	.80	.80	90.0	3.60	3.72	.14	.29	.32	51.70
9-1591- 1	71.0	71.0	1.80	1.80	157.6	27.37	28.49	.62	.71	.94	N/A
9-1591- 3	0.0	0.0	1.80	1.80	157.6	39.87	43.60	2.08	.53	2.14	N/A
9-1591- 4	72.0	70.0	2.80	2.80	157.6	42.30	46.53	1.51	.53	1.60	71.76
9-1592- 1	69.0	69.0	3.80	3.80	157.6	24.45	27.36	.77	.49	.91	68.83
9-1592- 2	69.0	69.0	2.80	2.80	157.6	26.98	29.31	.83	.57	1.01	38.06
9-1592- 3	71.0	71.0	5.80	5.80	157.6	19.66	23.82	.72	.54	.90	39.03
9-1592- 4	72.0	70.0	6.80	6.80	157.6	25.31	30.97	.83	.34	.90	122.31
9-1592- 6	70.0	69.0	2.80	2.80	157.6	20.46	22.39	.69	.69	.98	51.42
9-1592- 9	0.0	0.0	1.80	1.80	157.6	21.51	24.52	1.67	.60	1.78	N/A
9-1698- 1	71.0	70.0	1.80	1.80	144.3	18.08	20.17	1.16	.37	1.22	44.23
9-1698- 2	71.0	71.0	1.80	1.80	144.3	39.87	43.61	2.08	.38	2.12	67.73
9-1698- 3	72.0	70.0	1.80	1.80	144.3	13.32	14.45	.63	.34	.72	N/A
9-1698- 4	71.0	71.0	1.80	1.80	144.3	25.98	28.10	1.17	.17	1.19	36.97
9-1698- 5	71.0	72.0	1.80	1.80	144.3	31.34	32.86	.84	.19	.86	48.93
9-1818- 1	66.0	68.0	.80	.80	127.5	9.02	9.31	.37	.24	.44	35.02
9-1818- 2	69.0	68.0	1.80	1.80	127.5	24.01	27.27	1.81	.41	1.86	42.05
9-1818- 3	69.0	76.0	1.80	1.80	127.5	17.65	21.43	2.10	.39	2.14	29.37
9-1818- 4	68.0	69.0	1.80	1.80	127.5	32.47	37.72	2.92	.58	2.98	N/A
9-1818- 5	70.0	67.0	.80	.80	127.5	8.04	8.72	.84	.54	1.00	20.79
9-1818- 6	72.0	66.0	1.80	1.80	127.5	11.75	12.90	.64	.49	.81	32.56
9-1819- 1	67.0	68.0	.80	.80	127.5	8.32	8.78	.57	.49	.75	24.22
9-1819- 2	66.0	70.0	1.00	1.00	127.5	17.04	18.86	1.82	.47	1.88	36.16
9-1819- 3	67.0	67.0	1.00	1.00	127.5	36.15	39.20	3.05	.64	3.12	N/A
9-1819- 4	71.0	70.0	3.80	3.80	127.5	30.34	35.75	1.42	.40	1.48	72.91
9-1819- 5	67.0	69.0	.80	.80	127.5	6.45	6.88	.53	.26	.59	26.68
9-1819- 6	67.0	67.0	.80	.80	127.5	11.71	12.72	1.27	.67	1.43	33.82
9-1819- 7	72.0	67.0	1.80	1.80	127.5	5.58	6.29	.39	.43	.58	N/A
9-1819- 8	72.0	70.0	3.00	3.00	127.5	9.37	11.93	.85	.62	1.05	22.93
9-1854- 1	68.0	0.0	1.00	1.00	121.5	18.31	19.99	1.67	.59	1.77	26.97
9-1854- 2	67.0	70.0	1.80	1.80	121.5	20.06	21.14	.60	.56	.82	52.02
9-1854- 3	79.0	71.0	1.00	1.00	121.5	8.75	9.24	.49	.53	.72	27.34
9-1854- 4	69.0	70.0	.80	.80	121.5	16.57	17.46	1.12	.58	1.26	57.56
9-1854- 5	0.0	0.0	.80	.80	121.5	7.63	7.78	.19	.70	.73	N/A
9-1854- 6	80.0	70.0	4.80	4.80	121.5	22.49	27.37	1.02	.22	1.04	59.69
9-1854- 7	85.0	72.0	4.80	4.80	121.5	13.29	15.85	.53	.25	.59	65.23
9-1854- 8	84.0	72.0	1.80	1.80	121.5	16.05	17.65	.89	.51	1.03	60.69

PARTICLE	BACKGROUND Cam 1	Cam 2	-- EXPOSURE -- Cam 1	Cam 2	Sun Coel	- DISTANCE - Endpt1	Endpt2	--- VELOCITY --- Radial	Trnvse	Total	Size
9-1854- 9	81.0	73.0	1.80	1.80	121.5	30.30	30.92	.35	.58	.68	70.21
9-1854-11	82.0	72.0	.80	.80	121.5	12.54	13.12	.73	.31	.79	50.80
9-1854-12	70.0	69.0	.80	.80	121.5	14.33	14.67	.42	.52	.67	29.73
9-1854-13	69.0	69.0	.80	.80	121.5	16.72	17.63	1.13	.50	1.24	43.43
9-1854-14	69.0	69.0	.80	.80	121.5	14.87	15.76	1.11	.67	1.30	45.13
9-1854-15	69.0	69.0	.80	.80	121.5	10.95	11.22	.34	.48	.59	47.82
9-1854-16	83.0	72.0	1.80	1.80	121.5	13.82	14.85	.57	.50	.76	60.62
9-1854-17	83.0	71.0	1.80	1.80	121.5	10.82	12.01	.66	.56	.86	39.69
9-1854-18	83.0	71.0	1.80	1.80	121.5	19.66	20.23	.32	.20	.38	143.09
9-1854-19	84.0	73.0	1.80	1.80	121.5	10.65	12.22	.87	.44	.98	26.47
9-1854-20	82.0	72.0	3.80	3.80	121.5	23.61	28.75	1.35	.83	1.58	56.26
9-1854-21	85.0	70.0	.80	.80	121.5	13.90	14.31	.51	.71	.87	34.27
9-1854-22	83.0	72.0	.80	.80	121.5	11.59	11.76	.21	.51	.55	27.44
9-1854-23	82.0	71.0	2.80	2.80	121.5	16.14	18.89	.98	.54	1.12	33.83
9-1854-24	80.0	73.0	1.80	1.80	121.5	14.38	15.91	.85	.83	1.19	56.40
9-1854-25	81.0	73.0	2.80	2.80	121.5	11.72	13.04	.47	.44	.64	70.09
9-1855- 1	68.0	70.0	.80	.80	117.3	11.96	12.13	.22	.62	.66	44.41
9-1855- 2	68.0	68.0	.80	.80	117.3	17.91	18.67	.95	.73	1.19	46.51
9-1855- 3	78.0	70.0	.80	.80	117.3	6.60	6.71	.14	.70	.71	33.14
9-1855- 4	78.0	71.0	.80	.80	117.3	9.88	10.18	.37	.63	.73	25.37
9-1855- 5	68.0	71.0	1.00	1.00	117.3	14.86	15.22	.35	.25	.43	23.07
9-1855- 6	68.0	70.0	.42	.42	117.3	10.51	10.86	.83	.77	1.14	42.83
9-1855- 7	70.0	70.0	.80	.80	117.3	14.00	14.32	.40	.58	.70	50.87
9-1855- 8	75.0	70.0	.80	.80	117.3	8.09	8.29	.25	.50	.56	44.34
9-1855- 9	80.0	70.0	.80	.80	117.3	13.17	13.29	.15	.55	.57	43.60
9-1855-10	80.0	69.0	.80	.80	117.3	6.84	7.05	.26	.54	.60	27.39
9-1855-12	78.0	70.0	.80	.80	117.3	7.23	7.67	.55	.65	.85	28.11
9-1855-13	68.0	69.0	.80	.80	117.3	11.86	12.00	.17	.75	.77	44.45
9-1855-14	79.0	72.0	.80	.80	117.3	14.54	15.51	1.21	.60	1.35	36.38
9-1855-15	79.0	71.0	.80	.80	117.3	12.14	12.25	.14	.87	.88	36.45
9-1855-16	79.0	72.0	.80	.80	117.3	15.17	15.85	.85	.63	1.06	38.20
9-1855-17	81.0	71.0	.80	.80	117.3	19.34	19.60	.32	.54	.62	66.42
9-1855-18	80.0	72.0	.80	.80	117.3	10.39	10.75	.45	.84	.96	32.12
9-1855-19	80.0	72.0	.80	.80	117.3	10.42	10.64	.27	.60	.65	35.53
9-1855-20	76.0	72.0	.80	.80	117.3	7.76	8.05	.37	.44	.58	31.83
9-1855-22	70.0	69.0	.80	.80	117.3	11.43	11.48	.07	.52	.53	32.33
9-1855-23	67.0	70.0	.80	.80	117.3	9.70	9.79	.12	.51	.53	37.56
9-1855-24	69.0	71.0	.80	.80	117.3	14.05	15.02	1.21	.66	1.38	29.26
9-1856- 1	68.0	69.0	.80	.80	112.4	9.94	10.05	.13	.36	.39	20.29
9-1856- 2	67.0	70.0	.80	.80	112.4	16.17	16.42	.31	.58	.66	50.95
9-1856- 4	67.0	69.0	1.00	1.00	112.4	27.63	28.23	.61	.52	.80	79.34
9-1856- 5	68.0	70.0	1.80	1.80	112.4	24.47	28.10	2.01	.53	2.08	72.35
9-1856- 6	69.0	72.0	1.80	1.80	112.4	18.10	18.99	.50	.78	.93	45.49
9-1856- 7	69.0	69.0	1.80	1.80	112.4	20.02	22.00	1.10	.44	1.18	47.71
9-1856- 8	69.0	70.0	.80	.80	112.4	10.23	10.56	.41	.56	.69	41.08
9-1856- 9	75.0	71.0	.80	.80	112.4	12.46	13.05	.73	.59	.94	38.51
9-1856-10	73.0	70.0	.80	.80	112.4	13.67	13.96	.36	.78	.86	37.30
9-1856-11	78.0	72.0	1.00	1.00	112.4	17.45	17.89	.44	.83	.94	47.56
9-1856-12	75.0	70.0	.80	.80	112.4	11.83	12.04	.25	.47	.53	27.62
9-1856-13	70.0	71.0	.80	.80	112.4	13.79	14.22	.54	.77	.94	N/A

PARTICLE	BACKGROUND Cam 1	Cam 2	-- EXPOSURE -- Cam 1	Cam 2	Sun Coel	- DISTANCE - Endpt1	Endpt2	--- VELOCITY --- Radial	Trnvse	Total	Size
9-1856-14	72.0	71.0	.80	.80	112.4	11.81	12.13	.41	.73	.83	38.28
9-1856-15	76.0	70.0	.80	.80	112.4	12.03	12.55	.65	.94	1.14	39.68
9-1856-16	77.0	72.0	.80	.80	112.4	11.20	12.04	1.05	.57	1.20	40.74
9-1856-17	70.0	71.0	.80	.80	112.4	33.66	35.33	2.09	.48	2.14	74.29
9-1856-18	77.0	72.0	.80	.80	112.4	14.91	15.56	.82	.37	.90	61.01
9-1856-19	76.0	71.0	1.00	1.00	112.4	14.64	14.77	.13	.57	.59	29.93
9-1856-20	73.0	70.0	1.00	1.00	112.4	25.22	27.69	2.47	.59	2.54	63.54
9-1856-21	75.0	70.0	.80	.80	112.4	20.70	22.34	2.05	.50	2.11	33.30
9-2461- 1	70.0	80.0	.80	.80	127.6	14.99	15.14	.20	.12	.23	19.31
9-2461- 2	84.0	90.0	.80	.80	127.6	14.10	14.54	.55	.20	.59	28.40
9-2461- 3	66.0	67.0	.80	.80	127.6	18.00	19.25	1.57	.46	1.64	N/A
9-2461- 4	74.0	65.0	1.80	1.80	127.6	28.49	31.02	1.41	.21	1.42	N/A
9-2532- 1	70.0	73.0	3.80	3.80	133.9	15.98	18.28	.61	.26	.66	29.75
9-2532- 2	0.0	0.0	1.80	1.80	133.9	43.63	46.53	1.62	.50	1.69	N/A
9-2532- 3	0.0	0.0	2.80	2.80	133.9	10.41	11.83	.51	.24	.56	N/A
9-2856- 1	66.0	62.0	1.80	1.80	145.9	7.79	8.58	.44	.27	.52	25.85
9-2925- 1	74.0	59.0	1.80	1.80	130.4	18.13	19.39	.70	.25	.74	25.84
9-2925- 2	74.0	60.0	3.80	3.80	130.4	15.67	18.36	.71	.24	.75	34.42
9-2925- 3	74.0	59.0	2.80	2.80	130.4	35.72	42.23	2.32	.52	2.38	56.14
9-2925- 4	75.0	59.0	5.80	5.80	130.4	33.21	41.06	1.35	.65	1.50	65.28
9-2925- 5	0.0	0.0	.80	.80	130.4	15.00	15.86	1.07	.63	1.24	N/A
9-2925- 6	0.0	0.0	.80	.80	130.4	22.48	22.85	.47	.86	.98	N/A
9-2926- 1	65.0	60.0	1.80	1.80	114.7	17.18	18.84	.92	.23	.95	48.50
9-2926- 2	74.0	59.0	3.80	3.80	114.7	13.17	14.85	.44	.16	.47	19.60
9-2926- 3	73.0	59.0	2.80	2.80	114.7	13.55	14.69	.41	.09	.42	32.17
9-2949- 1	64.0	63.0	3.80	3.80	154.4	10.90	11.78	.23	.21	.31	41.40
9-2949- 2	66.0	64.0	.80	.80	154.4	19.04	19.57	.66	.19	.69	36.47
9-2949- 3	66.0	62.0	1.80	1.80	154.4	15.54	16.39	.53	.50	.73	35.28
9-2949- 4	66.0	62.0	2.80	2.80	154.4	15.68	16.57	.32	.25	.40	37.26
9-2949- 5	68.0	62.0	1.80	1.80	154.4	17.14	17.55	.23	.26	.34	49.66
9-2949- 6	67.0	63.0	3.80	3.80	154.4	16.27	19.34	.96	.54	1.10	42.50
9-2949- 7	66.0	63.0	5.80	5.80	154.4	13.97	15.42	.25	.24	.35	54.21
9-2949- 8	67.0	63.0	2.80	2.80	154.4	11.73	12.57	.30	.23	.38	47.42
9-2949- 9	66.0	62.0	2.80	2.80	154.4	13.29	13.82	.19	.16	.25	99.75
9-3175- 1	65.0	60.0	.80	.80	133.2	7.68	7.94	.33	.60	.68	28.39
9-3175- 2	64.0	61.0	.80	.80	133.2	7.55	7.94	.49	.65	.82	29.42
9-3175- 3	64.0	59.0	.80	.80	133.2	6.45	6.64	.24	.67	.71	N/A
9-3175- 4	65.0	59.0	.80	.80	133.2	12.69	12.81	.14	.75	.76	49.31
9-3176- 1	64.0	61.0	.80	.80	133.2	22.32	24.31	2.49	1.01	2.69	N/A
9-3176- 2	65.0	60.0	.80	.80	133.2	12.48	13.22	.93	1.00	1.36	N/A
9-3176- 3	64.0	60.0	.80	.80	133.2	9.43	9.56	.16	.96	.97	35.42
9-3176- 4	63.0	59.0	.80	.80	133.2	11.79	12.30	.64	.65	.91	31.65
9-3176- 5	62.0	59.0	.80	.80	133.2	8.78	9.23	.55	.79	.97	25.55
9-3176- 6	61.0	60.0	.80	.80	133.2	9.66	10.04	.47	1.12	1.22	N/A
9-3177- 1	62.0	61.0	.80	.80	133.2	11.08	11.37	.37	.61	.71	24.07
9-3177- 2	65.0	0.0	.80	.80	133.2	9.42	9.89	.59	.88	1.05	N/A
9-3177- 3	64.0	62.0	.80	.80	133.2	8.18	8.85	.83	.73	1.10	27.69
9-3177- 4	65.0	0.0	.80	.80	133.2	13.47	13.92	.56	.78	.96	N/A
9-3177- 5	64.0	61.0	.80	.80	133.2	10.72	11.24	.65	.66	.93	27.62
9-3177- 6	65.0	0.0	.80	.80	133.2	10.64	10.81	.21	.70	.73	N/A

PARTICLE	BACKGROUND Cam 1	Cam 2	-- EXPOSURE -- Cam 1	Cam 2	Sun Coel	- DISTANCE - Endpt1	Endpt2	--- VELOCITY --- Radial	Trnvse	Total	Size
9-3177- 7	64.0	60.0	.80	.80	133.2	9.36	9.55	.24	.52	.57	36.54
9-3177- 8	65.0	0.0	.80	.80	133.2	13.22	13.44	.28	.97	1.01	N/A
9-3177- 9	65.0	0.0	.80	.80	133.2	15.88	16.61	.92	.65	1.13	N/A
9-3178- 1	65.0	0.0	.80	.80	133.2	12.81	13.30	.61	.76	.98	N/A
9-3178- 2	65.0	0.0	.80	.80	133.2	12.16	12.95	.98	.62	1.16	N/A
9-3213- 1	64.0	78.0	.80	.80	119.3	7.58	7.63	.05	.59	.59	48.15
9-3214- 1	0.0	0.0	.80	.80	119.3	18.37	18.61	.31	.47	.56	N/A
9-3214- 2	0.0	0.0	.80	.80	119.3	4.57	4.63	.07	.05	.09	N/A
9-3215- 1	61.0	58.0	.80	.80	119.3	12.49	12.50	.01	.40	.40	19.69
9-3215- 2	62.0	58.0	.80	.80	119.3	6.65	6.84	.24	.09	.26	18.94
9-3215- 3	87.0	60.0	.80	.80	119.3	10.42	10.66	.30	.14	.33	17.22
9-3283- 1	112.0	81.0	.80	.80	144.4	11.08	11.24	.20	.21	.29	21.14
9-3283- 2	127.0	92.0	.80	.80	144.4	8.18	8.66	.60	.40	.72	25.63
9-3283- 3	0.0	0.0	.80	.80	144.4	8.22	8.64	.52	.37	.64	N/A
9-3496- 1	63.0	58.0	.80	.80	108.8	7.22	7.42	.25	.16	.29	19.13
9-3496- 2	60.0	58.0	.80	.80	108.8	7.93	8.16	.29	.14	.32	16.43
9-3496- 3	61.0	59.0	.80	.80	108.8	7.78	7.97	.23	.15	.27	21.63
9-3496- 4	74.0	72.0	.80	.80	108.8	12.80	13.04	.30	.26	.39	29.83

APPROVAL

ANALYSIS OF CONTAMINATION DATA RECORDED BY THE IECM CAMERA/PHOTOMETER

By K. Stuart Clifton and Carl M. Benson

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

E. Tandberg-Hanssen

E. TANDBERG-HANSSEN
Director, Space Science Laboratory

* GOVERNMENT PRINTING OFFICE: 1988 - 530050 / 80035